SPECIAL ASTRONOMY SECTION Telescope revivals, astronaut life and more! p.59

SCIENCE FOR THE CURIOUS

Discover®

March 2016

Rethinking Our Origins

NEW FOSSILS MAY REWRITE EVOLUTION'S TIMELINE p.28

PLUS

Sex on the Brain p.52

Can We Stop the Blackout of the Century? p.44

Get That Song Outta My Head! p.22

Hidden Danger of Life in Space p.66

BONUS ONLINE CONTENT CODE p. 5

Introducing Kyrobak®, the only home-use device using professional **Oscillation Therapy** and **Continuous Passive Motion** (CPM) technology, recommended by doctors worldwide, that's **clinically proven*** to bring you...

LASTING RELIEF *from* BACK PAIN

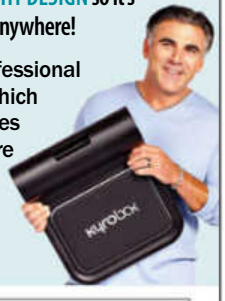
GET RELIEF NOW RISK FREE FOR 60 DAYS

- **CLINICALLY PROVEN*** treatment for lower back pain relief in the comfort of your home
- **LASTING RELIEF** experienced, even up to 3 weeks after usage has stopped
- **FAST & CONVENIENT** just 10 minutes
- **SAVES MONEY** no more expensive trips to the doctor
- **UNIQUE TECHNOLOGY** benefit from proven Oscillation Therapy + Continuous Passive Motion technology
- **EASY TO USE** on the floor, bed or couch
- **NATURAL TREATMENT** with no painkillers or prescription drugs needed
- **COMPACT, LIGHTWEIGHT DESIGN** so it's easy to use and store anywhere!

DOCTOR RECOMMENDED

"What makes Kyrobak so effective is the unique CPM technology it provides to muscles and joints. This specific type of motion reduces inflammation and sends important signals to the nervous system to restore muscle tone, balance and blood supply."

DR. STEVEN GEANOPULOS, CHIROPRACTIC NEUROLOGIST



Kyrobak uses a professional technology, CPM, which loosens tight muscles and releases pressure between the vertebrae in your spine to relieve back pain.

TAKES JUST 10 MINUTES

Introducing Kyrobak, the new device that uses professional technology for personal use to deliver lasting results — and it takes just 10 relaxing minutes!

Kyrobak is clinically proven* to treat lower back pain and provide lasting relief. For many users, it offers a drug-free alternative to the constant requirement for powerful painkillers.

And, in a recent clinical study, Kyrobak was shown to continue to provide pain relief even 3 weeks after usage was stopped!

Now, for the first time ever, Oscillation Therapy and Continuous Passive Motion technology, as used by medical professionals, are available in this doctor-recommended, home-use device. Just 10 relaxing minutes is all it takes for Kyrobak to deliver lasting relief for your lower back pain.

"Ten minutes and then I'm free to do the things I love without pain, without worrying if something is going to stop me from enjoying life."
Ken S., Museum Curator

"I've been battling this pain for about 14 years and I've taken painkillers, muscle relaxants, prescription drugs... but I haven't had to take a single thing since I started on the Kyrobak. I just love not having to have all these chemicals in my body and it gives me so much more energy!"
Celeste, Dance Instructor

DISCOVER THE KYROBAK ADVANTAGE

With Kyrobak, you will get much more than momentary relief. The longer Kyrobak users continued treatment, the more relief they reported.

Kyrobak is convenient and easy to use! It's lightweight and portable, too! Move Kyrobak from room to room with ease ... in fact, you can take it with you wherever you go!

Call now for more details on your 60-Day Risk-Free Trial and put an end to the agony of back pain for good!

— 100% — **RISK FREE 60-DAY TRIAL**

If you don't LOVE your Kyrobak, simply return it within 60 days and we will refund all your money PLUS pay the return postage. Call for details!

Kyrobak works on the floor, the sofa ... even on your bed!

You do not have to be physically fit to use Kyrobak. You can enjoy your treatment while in complete rest, on the floor, your bed or even on the couch.

3 SIMPLE STEPS TO LASTING RELIEF

STEP 1
PLUG IN!

ABSOLUTELY NO ASSEMBLY REQUIRED BEFORE USE

STEP 2
LIE DOWN!

SO EASY TO USE! SIMPLY CLOSE YOUR EYES AND RELAX

STEP 3
TURN ON!

AUTO SWITCH-OFF AFTER EACH 10-MINUTE TREATMENT

NO ASSEMBLY NEEDED

kyrobak Try it now! **RISK-FREE FOR 60 DAYS**

You have nothing to lose but the agony of lower back pain!

CALL NOW 1-800-410-6780

or discover more at www.KyroOffer399.com

*With Oscillation Therapy and Continuous Passive Motion. Clinically proven in multiple clinical studies. Data on file.

Own the "Gem of the Century"

Incredibly rare find is now available to the public for ONLY $59!

For centuries, the "Big Four"—diamonds, rubies, emeralds and sapphires—ruled the gem world. When tanzanite debuted in 1967, it was a sensation. Unlike those other stones, which are mined all over the world, tanzanite can be found in only one place on Earth: in the remote Merelani Hills in the shadow of Mt. Kilimanjaro in Tanzania, Africa.

HUGE SAVINGS
TAKE 85% OFF THE KARATU TANZANITE RING
WHEN YOU USE YOUR OFFER CODE

Gem of the century meets deal of the century. With its remarkable rarity and unique gemstone qualities. it's no wonder that experts have dubbed it, "the gemstone of the 20th century." In recent years, top-quality tanzanite gems have fetched higher prices at auction than rubies, emeralds or diamonds! But because we buy direct and use our own designers, we are able to offer you this rare beauty for **ONLY $59!**

What makes tanzanite so irresistible to jewelers and gem experts? Part of its appeal is the beautiful violet blue color. Tanzanite is also trichroic—which means that three different colors are visible when the stone is viewed from different angles.

"This ring is unbelievable. I've owned some spectacular high-dollar gemstones in my life and this ring will compete with any of them!" —Katharine, Shreveport, LA

Henry Platt, past president and chairman of Tiffany & Company, called Tanzanite "The most important gemstone discovery in over 2,000 years."

A gemstone found only one place on earth, means supply is extremely limited. Get your hands on the *Karatu Tanzanite Ring* before they're gone!

Your satisfaction is 100% guaranteed. Experience the rare beauty of the *Karatu Tanzanite Ring* for two months. If you're not completely awestruck, simply send it back within 60 days for a complete refund of the sale price. We want you to feel like you got the deal of the century!

With over 4,000 sold, we currently have less than 2,000 in stock!

Karatu Tanzanite Ring ~~$399*~~

Offer Code Price *Only* $59 + S&P *Save $340!*

You must use the insider offer code to get our special price.

1-800-333-2045

Your Offer Code: KTR176-02
Please use this code when you order to receive your discount.

Stauer®
14101 Southcross Drive W., Dept. KTR176-02,
Burnsville, Minnesota 55337 www.stauer.com

ACCREDITED BUSINESS BBB **Rating of A+**

CONSUMER AFFAIRS ACCREDITED

** Special price only for customers using the offer code versus the price on Stauer.com without your offer code.*

1 1/5 carats of geniune tanzanite • Lab-created white DiamondAura accents • .925 sterling silver setting • Whole ring sizes 5–10

Smart Luxuries—Surprising Prices™

Contents

MARCH 2016
VOL. 37, NO. 2

COVER STORY

Rethinking Our Roots

For 50 years, we've looked to East Africa as the potential birthplace of our genus and species. But a growing number of sites in South Africa suggest our roots may lie there.

STORY AND PHOTOS BY RUSS JUSKALIAN

Archaeologist Dominic Stratford works at an excavation site in South African caves.

ON THE COVER *Photograph by Russ Juskalian*

FEATURES

COLUMNS & DEPARTMENTS


p.24


p.66

Asked and Answered

A simple question yields a wealth of answers.

Back in our December issue, I posed a simple question: *Is there a science topic we don't cover in one of our columns that you'd like to see in future issues?*

I've been asking questions like this for a few years now, and I never know how (or even if) readers will respond. But my December query garnered one of the largest responses ever — nearly 40 letters in one afternoon alone, and they're still coming in!

Some of you wanted to see the return of long-lost departments, such as the mystery photos we used to ask readers to identify, or the brain games column that *Discover* once published several years back. (Guess what? One of these will return, sooner than you think.)

Other readers asked for stories that, it turns out, we already deliver. Roger W. wished for a column with "follow-up stories from past issues where the subject was left with no definitive conclusion or an outcome that may happen in years to come." Fred D. requested a regular spot where "readers could send their questions (but make them short and sweet)."

Well, follow-up stories are exactly what we offer in ReDiscover, and we already get an abundance of reader questions for Ask Discover, both of which appear from time to time in the pages of The Crux, which begins this issue on page 7. Nevertheless, I'm grateful to Roger and Fred because their requests tell me that, while we do run such items regularly, clearly we don't run them regularly enough, so look for more in future issues.

Many of you had ideas that revolved around similar topics. There's evidently a great deal of interest in a column that focuses on medical news and breakthroughs. And lots of folks asked for regular stories that dabble in a bit of futurism, offering a glimpse of what our world will look like in 20, 50, 100 or more years if current scientific research and discoveries are allowed to achieve their fullest potential (for better or worse).

Well, we've heard you, friends. I've shared your letters with the editorial team, and I think you can look forward to seeing your feedback informing issues of *Discover* throughout 2016 and beyond.

And why shouldn't it? It is, after all, your magazine, too. There's no question about that.

Stephen C. George, **EDITOR IN CHIEF**

CONNECT WITH US

facebook.com/DiscoverMag
twitter.com/DiscoverMag
plus.google.com/+discovermagazine

Discover
SCIENCE FOR THE CURIOUS

STEPHEN C. GEORGE Editor In Chief
DAN BISHOP Design Director

EDITORIAL
KATHI KUBE Managing Editor
BECKY LANG Senior Editor
BILL ANDREWS Senior Associate Editor
GEMMA TARLACH Senior Associate Editor
APRIL REESE Associate Editor
LACY SCHLEY Assistant Editor
DAVE LEE Copy Editor
ELISA R. NECKAR Editorial Assistant

Contributing Editors
DAN FERBER, TIM FOLGER, LINDA MARSA, STEVE NADIS, ADAM PIORE, COREY S. POWELL, JULIE REHMEYER, ERIK VANCE, STEVE VOLK, PAMELA WEINTRAUB, JEFF WHEELWRIGHT, DARLENE CAVALIER (SPECIAL PROJECTS)

ART
ERNIE MASTROIANNI Photo Editor
ALISON MACKEY Associate Art Director

DISCOVERMAGAZINE.COM
CARL ENGELKING Web Associate Editor
NATHANIEL SCHARPING Web Staff Writer

Bloggers
MEREDITH CARPENTER, LILLIAN FRITZ-LAYLIN, JEREMY HSU, REBECCA KRESTON, JEFFREY MARLOW, NEUROSKEPTIC, ELIZABETH PRESTON, SCISTARTER, CHRISTIE WILCOX, TOM YULSMAN

ADVERTISING
STEVE MENI Advertising Sales Manager
888 558 1544
smeni@discovermagazine.com

Rummel Media Connections
KRISTI RUMMEL Consulting and Media Sales
608 435 6220
kristi@rummelmedia.com
MELANIE DECARLI Marketing Architect
BOB RATTNER Research
DARYL PAGEL Advertising Services

KALMBACH PUBLISHING CO.
CHARLES R. CROFT President
KEVIN P. KEEFE Vice President, Editorial
DANIEL R. LANCE Senior V.P., Sales & Marketing
JAMES R. MCCANN Vice President, Finance
NICOLE MCGUIRE Vice President, Consumer Marketing
JAMES SCHWEDER Vice President, Technology
DIANE M. BACHA Editorial Director
ANN E. SMITH Corporate Advertising Director
MAUREEN M. SCHIMMEL Corporate Art Director
KIM REDMOND Single Copy Specialist
MIKE SOLIDAY Art and Production Manager

SUBSCRIPTIONS
In the U.S., $29.95 for one year; in Canada, $39.95 for one year (U.S. funds only), includes GST, BN 12271 3209RT; other foreign countries, $44.95 for one year (U.S. funds only).

CUSTOMER SALES & SERVICE
800 829 9132
Outside the U.S. and Canada: 813 910 3616
Customer Service: Discover@customersvc.com
Digital: Discover.Digital@customersvc.com
Back issues: Discover.SingleCopy@customersvc.com

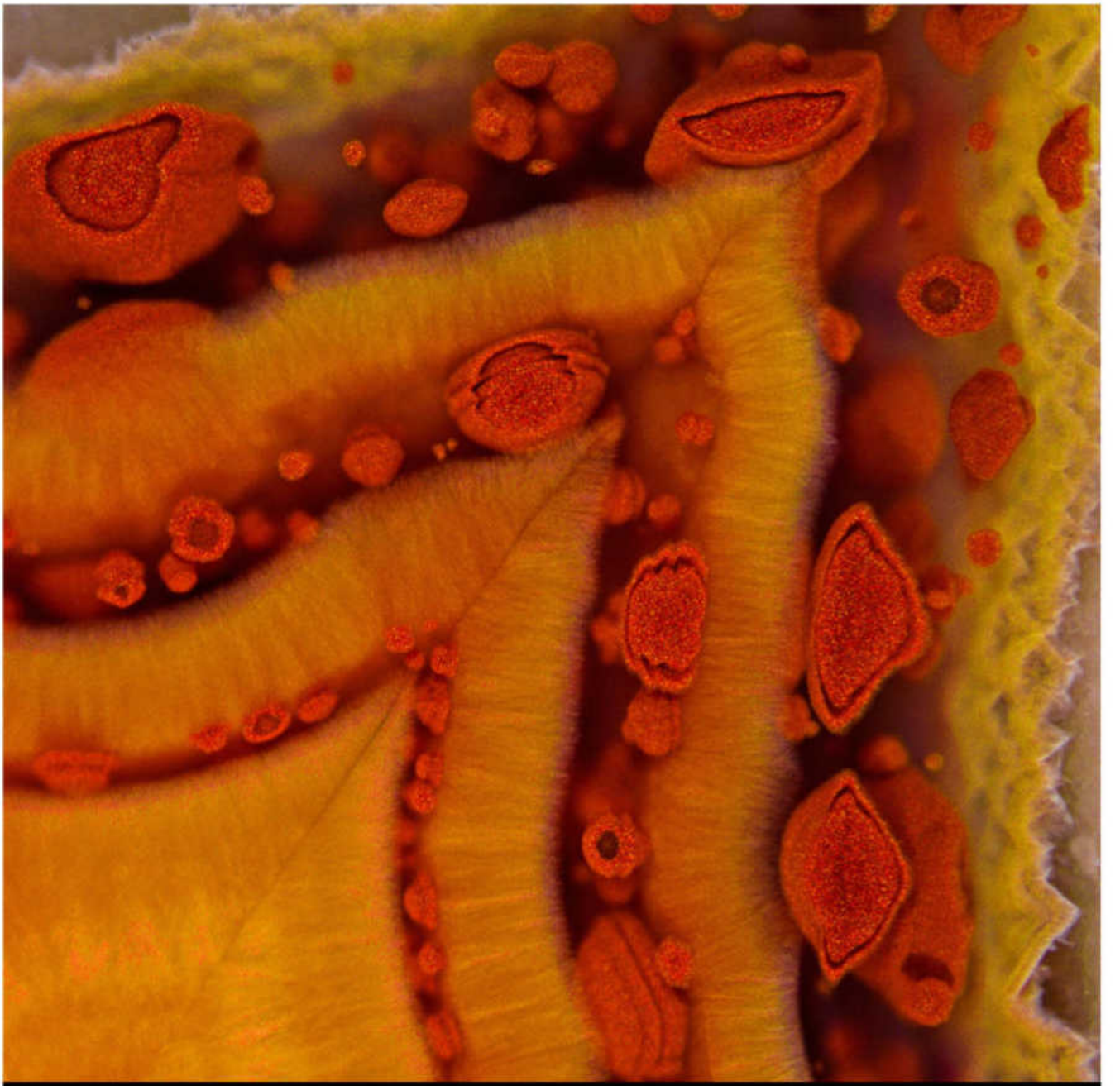
EDITORIAL INQUIRIES
editorial@DiscoverMagazine.com
21027 Crossroads Circle, Waukesha, WI 53186

Alliance for Audited Media
KALMBACH PUBLISHING CO.

WILLIAM ZUBACK/DISCOVER

THE CRUX

The Latest Science News & Notes



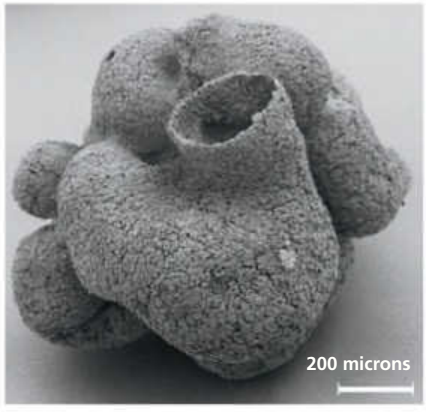
ROCK OUT
A slice of Fairburn agate from the Black Hills of South Dakota looks positively biological at around 60x magnification. The blobs that look like red blood cells are iron oxide particles, forced into bands during the gemstone's crystallization 295 million years ago, says photographer Douglas Moore, senior media specialist at the University of Wisconsin-Stevens Point. Named after the South Dakota town where it's most common, Fairburn is among the rarest types of agate in North America. This photo was selected as an Image of Distinction in the Nikon Small World Photomicrography Competition in 2015. — ERNIE MASTROIANNI; PHOTO BY DOUGLAS MOORE

Filled: A 600-Million-Year-Old Gap in the Fossil Record

Evidence of a sea sponge ancestor connects evolutionary dots.

A fossil smaller than a sesame seed has revealed the invisible early history of animals on Earth and could reconcile a major evolutionary paradox. Previous phylogenetic studies, which model the evolution of groups of related organisms, have suggested that the animals that gave rise to sea sponges, sea anemones, worms and crustaceans first appeared 600 million to 700 million years ago. But until now, scientists had no undisputed fossil evidence of any animals at all prior to about 575 million years ago.

The new fossil, apparently an ancestor of the Precambrian sea sponge, was found in 600-million-year-old rocks in China. Its hundreds of thousands of microscopic cells are



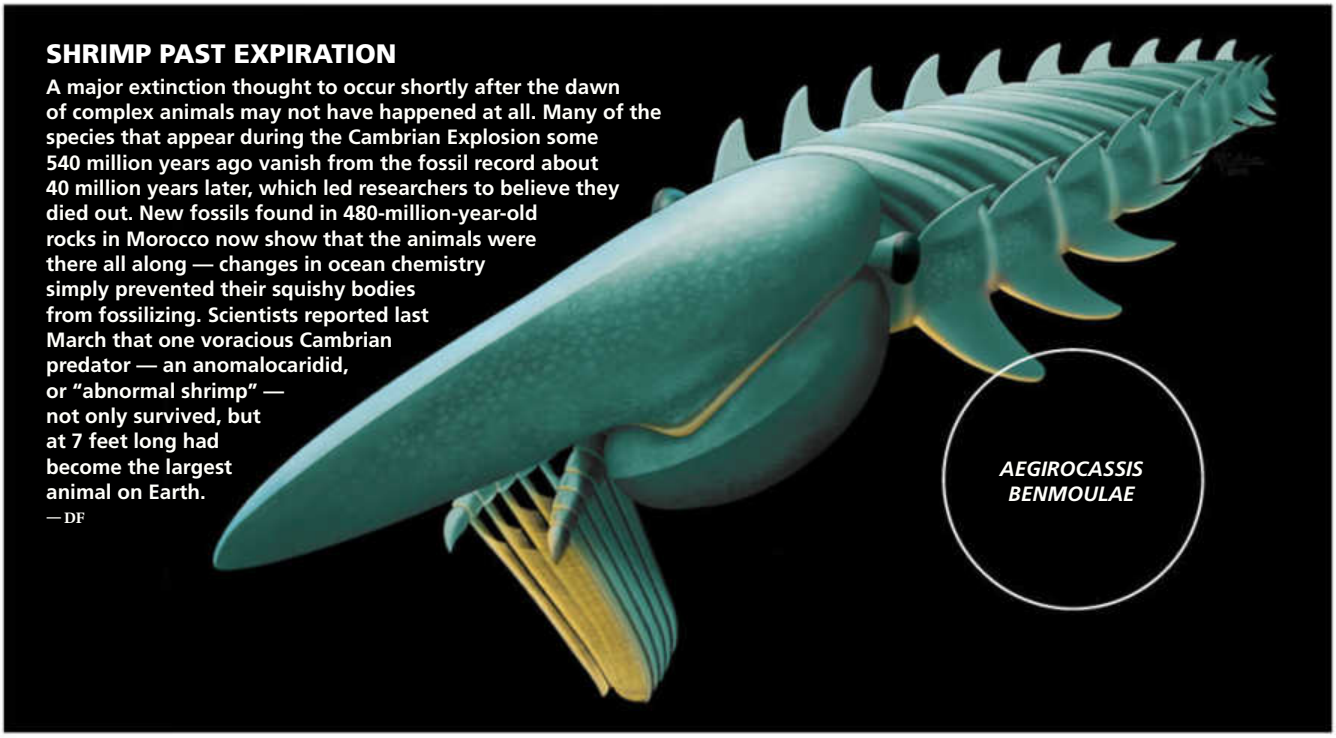
spectacularly preserved in phosphate minerals. The body consists of three vaselike openings, the walls perforated by tiny pores — just like modern sponges, which pump water through the holes to filter out food.

Previously, these same rocks have yielded minuscule fossils, containing eight or 16 cells, thought to be sponge embryos. The new fossil is more convincing because it finally shows an adult animal, says Eric Davidson, a developmental biologist at the California Institute of Technology and part of the team that reported the fossil last March.

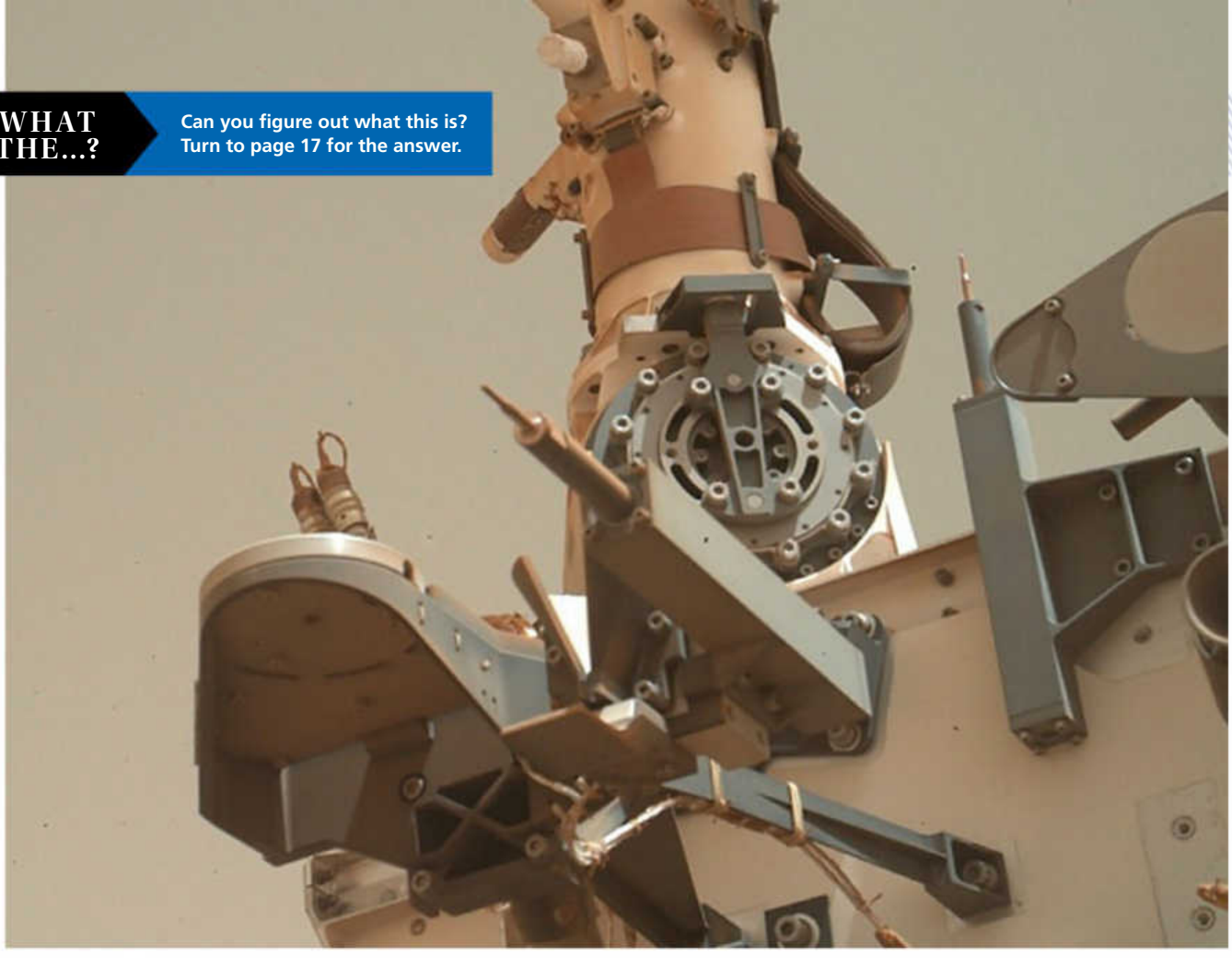
The rock layer in southern China, called the Doushantuo Formation, is famous for its microfossils. "It probably holds the secret of early animal life," says Davidson, who believes that fossils yet to be found will paint a clearer picture of the first emergence of complex life. "Somebody's got to just do the digging." — DOUGLAS FOX

SHRIMP PAST EXPIRATION

A major extinction thought to occur shortly after the dawn of complex animals may not have happened at all. Many of the species that appear during the Cambrian Explosion some 540 million years ago vanish from the fossil record about 40 million years later, which led researchers to believe they died out. New fossils found in 480-million-year-old rocks in Morocco now show that the animals were there all along — changes in ocean chemistry simply prevented their squishy bodies from fossilizing. Scientists reported last March that one voracious Cambrian predator — an anomalocaridid, or "abnormal shrimp" — not only survived, but at 7 feet long had become the largest animal on Earth.
— DF



TOP: MAYOAN ZHU ET AL/PNAS 112 MARCH 9, 2015: E1453-E1460. BOTTOM: RECONSTRUCTION BY MARIANNE COLLINS/ARTOFFACT VIA YALE UNIVERSITY



WHAT THE...? Can you figure out what this is? Turn to page 17 for the answer.

INBOX

Splashdown Snack

Christian Millman's History Lessons story on "The Care and Feeding of Astronauts" in the December 2015 issue sparked one reader's memories of a special space snack.

Before there was food in a toothpaste tube, before Alan Shepard was named as our very first astronaut to visit the outer limits, before we had knowledge to build upon, we had to plan. I was fortunate enough, in 1958 to 1959, to be invited to participate in the postdoctoral seminars that studied these challenges at the University of Michigan's Human Factors group under the leadership of Paul Fitts.

Shepard, on his initial suborbital flight (May 5, 1961), carried an item with him that I not only specified, but successfully argued for. He never used it. I had predicted he wouldn't. But it was there for him, and that was important. Can you guess what it was?

The Mercury program was very weight conscious; every ounce had to be considered as an effect on liftoff, flight and landing. I was sitting in on a think tank conference as the specialist in physiological psychology. We were pondering the personal items that were to be carried on the flight. Remember, no one had ever done what Shepard was scheduled to do.

The conference's purpose was to determine all the things that could go wrong and to define the defenses against those things. One of the outcomes of the exercise was the possibility that pickup after splashdown might be delayed by as much as several hours. Nutritionists on the medical staff convinced everyone that Shepard would not starve to death in that period. I countered with the need for psychological well-being and recommended that some food be taken along. For physical reasons, Shepard supposedly was going into this flight with an empty stomach. With all the functions that he was to perform preflight and post-flight, he would be too involved to think about hunger pangs. However, a delayed pickup, with the space capsule bobbing in the ocean for several hours, would provide a great opportunity to think about his situation. At the least, the hunger would become a discomfort. At the most, it could lead to distraction from mission objectives.

With only a couple of ounces to contribute, a candy bar was considered acceptable. It then took a discussion of several minutes to decide which candy bar would be chosen. Because of possible conflicts with potential sponsorships, we were sworn to secrecy. I think the statute of limitations would allow me to tell you Milky Way won out over a Mars bar! Shepard never removed the Milky Way from his pocket and probably did not think about it. But I felt better, knowing it was there!

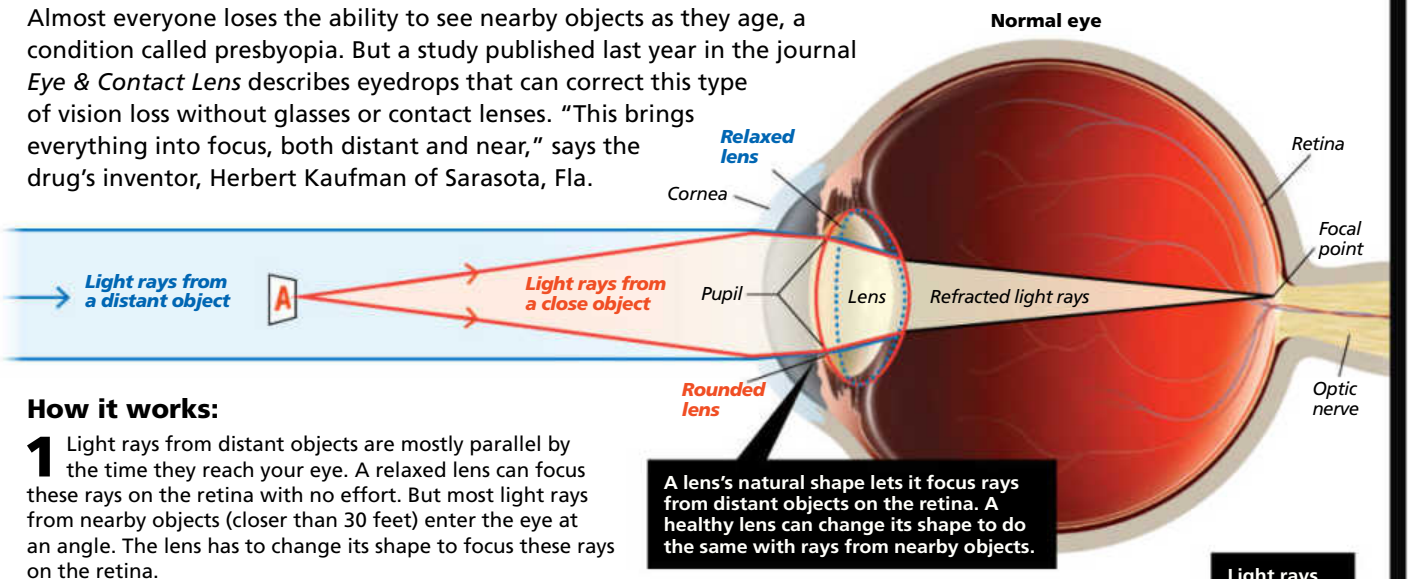
Bob Hooson
Social Circle, GA

CANDY BARS: MARS INC.

A Drop of Relief

Corrective eyedrops could help you ditch your reading glasses.

Almost everyone loses the ability to see nearby objects as they age, a condition called presbyopia. But a study published last year in the journal *Eye & Contact Lens* describes eyedrops that can correct this type of vision loss without glasses or contact lenses. "This brings everything into focus, both distant and near," says the drug's inventor, Herbert Kaufman of Sarasota, Fla.

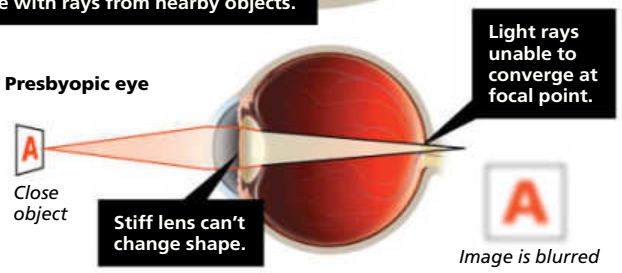


How it works:

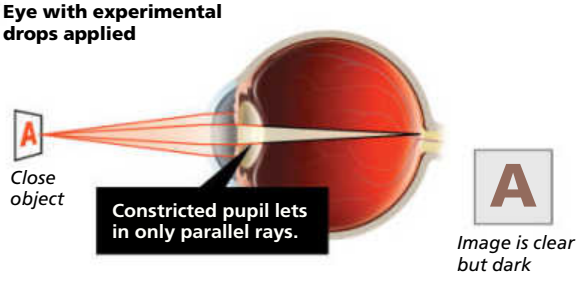
1 Light rays from distant objects are mostly parallel by the time they reach your eye. A relaxed lens can focus these rays on the retina with no effort. But most light rays from nearby objects (closer than 30 feet) enter the eye at an angle. The lens has to change its shape to focus these rays on the retina.

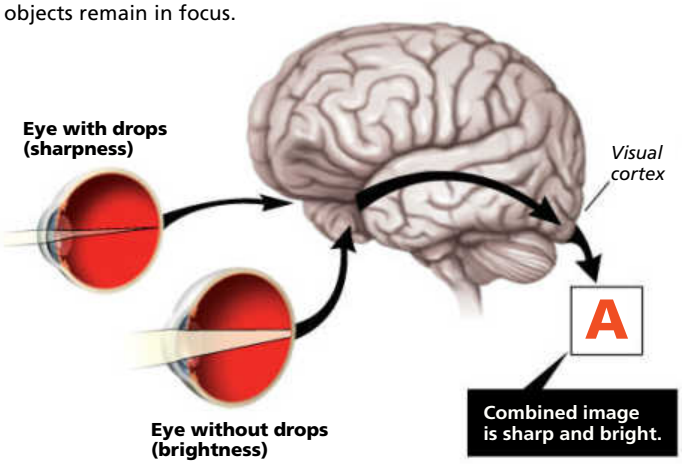
2 As we age, the lens becomes stiff. It can still process distant objects with its natural shape, however stiff it is. But a presbyopic lens can no longer change to focus peripheral rays from nearby objects.

Reading glasses bend these peripheral rays. Seen through these artificial lenses, nearby objects are in focus, but distant objects are out of focus.



3 The experimental new eyedrops combine two existing drugs, carbachol and brimonidine, which work together to temporarily constrict the pupil. This creates a pinhole camera effect. Pinholes do not bend light rays. Instead, they allow only the central light rays to pass through. Since these rays don't hit the eye at multiple angles, the lens doesn't need to change its shape. Both distant and near objects remain in focus.





4 With a smaller pupil, the eye admits less light. So the user puts the drops only in one eye. The brain combines the bright, blurry image from one eye with the sharp, dark image from the other to create an image that is both bright and sharp.

In the study, which included 48 people, the drops improved near vision well enough to read without glasses in the first hour. After that, the pupils gradually dilated, and vision declined over the next 10 hours, so the subjects had to put in new drops each morning. Kaufman hopes to find a drug company that will soon produce and market the eyedrops.

—LAIRD HARRISON

ROEN KELLY/DISCOVER

FREE Cultured Pearls
Limited to the first 1900 responders to this ad only!

CLIENTS LOVE STAUER JEWELRY...
"I couldn't believe it, but decided to call and I've not been disappointed since. I received the necklace and keep coming back for more."
— Amy, Fairmont, WV

How Do You Spell Pearl Necklace? F-R-E-E.

*Experience the luxury of Genuine Cultured Pearls...FREE!**

You read that right. If you'd like the Stauer genuine 26" cultured pearl necklace absolutely **FREE***, all you need to do is call us today. There is no catch. If you're wondering exactly how we can do this... read on.

This stunning, romantic necklace never goes out of style. In a world where some cultured pearl necklaces can cost thousands, shop around and I doubt that you will see any jewelry offer that even comes close.

Stauer has had a very good year and it's time for us to give back. That's why we're offering this stunning, 26" strand of genuine cultured white pearls for **FREE!** You pay only $24.95 for shipping & processing, our normal fee for a $295 necklace...and we'll even ***pay you back with a $25 Discount Certificate— that's our BETTER THAN FREE Shipping!***

"Each Mitsuko® cultured pearl is harvested, polished and strung by hand."
— James T. Fent, Stauer GIA Certified Gemologist

Why would we do this? Our real goal is to build a long term client relationship with you. We are sure that most of you will become loyal Stauer clients in the years to come, but for now, while luxury prices soar, we will give you these classic pearls so you can treat yourself or someone you love without the outrageous price tag.

We did find a magnificent cache of cultured pearls at the best price that I have ever seen. Our pearl dealer was stuck. A large foreign luxury department store in financial trouble cancelled a massive order at the last minute, so instead, we grabbed all of those gorgeous pearls. He sold us an enormous cache of his roundest, whitest, most iridescent cultured 6 ½–7 ½ mm pearls for only pennies on the dollar.

But let me get to the point: his loss is your gain. Many of you may be wondering about your next gift for someone special. This year, we've really come to the rescue.

For the next few days, I'm not offering this cultured pearl necklace at $1,200. I'm not selling it for $300. That's because I don't want to SELL you these cultured pearls at all... I want to ***GIVE*** them to you for **FREE!**

It's okay to be skeptical. But the truth is that Stauer doesn't make money by selling one piece of jewelry to you on a single occasion. We do well by serving our long term clients. And as soon as you get a closer look at our exclusive selection including millions of carats of emeralds, rubies, sapphires, tanzanite and amethyst, you're not going to want to buy your jewelry anywhere else.

Too good to pass up. Too good to last long. Genuine cultured pearls are a luxurious statement. Stauer finds a deal this outrageous once every few years. We have sold over 200,000 strands of pearls in the last several years and this is our finest value ever**. There is only a limited quanity left in stock,** so when they're gone, they're GONE! Call to reserve your **FREE *Cultured Pearl Necklace*** today and experience a brilliant new definition of *price*-less luxury!

Mitsuko® Cultured Pearl Necklace (26" strand) ~~$295~~**

Your Cost With Offer Code*— FREE

***pay only shipping & processing of $24.95.**

You must use the offer code below to receive this special free necklace.

1-800-333-2045

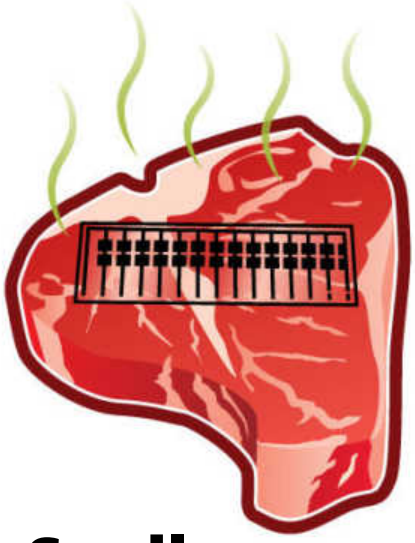
Offer Code MFP332-03
Mention this code to receive free necklace.

Rating of A+

Stauer® 14101 Southcross Drive W., Dept. MFP332-03, Burnsville, Minnesota 55337 www.stauer.com

* This offer is valid in the United States (and Puerto Rico) except in TX, FL, CO, OK, RI, NH, WV, OR, SC, VA and ID. These state residents will be charged one cent ($.01) + shipping & processing for the item. Void where prohibited or restricted by law. Offer subject to state and local regulations. Not valid with any other offers and only while supplies last. This offer is limited to one item per shipping address. ** *Free is only for customers using the offer code versus the price on Stauer.com without your offer code.*

Smart Luxuries—Surprising Prices™



Spoiler Alert

Let science sniff those iffy leftovers for you.

It's a question we've all faced: When you find a cache of long-forgotten meat in the back of the refrigerator, do you throw it out and waste money, or eat it and risk intestinal distress? MIT researchers think they have the answer.

Chemistry professor Timothy Swager and colleagues ran a minute electrical current through tiny cylinders of carbon atoms called nanotubes to detect compounds that rotting meat exudes — chemicals with evocative names like *putrescine* and *cadaverine*. As microbial activity increased, so did the compounds' levels, changing the electrical signals and indicating the meat was past its prime.

The company C2Sense, which licensed the technology, is working on creating portable prototypes that will encapsulate the nanotubes and a tiny battery in semipermeable, food-safe material.

With C2Sense beginning field tests later this year, Swager thinks that commercial sensors will appear soon at a grocery store near you. The paper-thin, credit card-size sensors on meat packaging may display text such as, "Eat in X days," or have a simple color readout: green (safe), yellow (eat soon) or red (time for the trash).

—KATHERINE KORNEI

The Truth About I-talk

Does pronoun overuse indicate narcissism?

Mine, me, I. Conventional thinking holds that narcissists overuse these first-person pronouns. *Au contraire*, says research from the University of Arizona.

The common association between narcissism and the high use of those pronouns, known as I-talk, is rooted in a 1988 study from the University of California, Berkeley. Back then, researchers tested just 48 participants, and subsequent similar experiments haven't replicated the finding.

So Matthias Mehl, an associate psychology professor at Arizona, launched the most robust examination to date of the relationship between I-talk and narcissism. Mehl and his team collaborated with researchers from six universities — four in the U.S. and two in Germany — and asked more than 4,800 people to complete a communication task in which participants either talked or wrote about themselves. Participants also completed a narcissism assessment.

When the team looked at the results, it turned out those who hit high marks on the narcissism assessment didn't carry on with excessive I-talk any more than those with low narcissism scores.

"The layperson in me was surprised," says Mehl. "When I listen to somebody who uses 'I' a lot, it's very hard to not make the inference that this person is self-absorbed … but it's not true."

—LACY SCHLEY

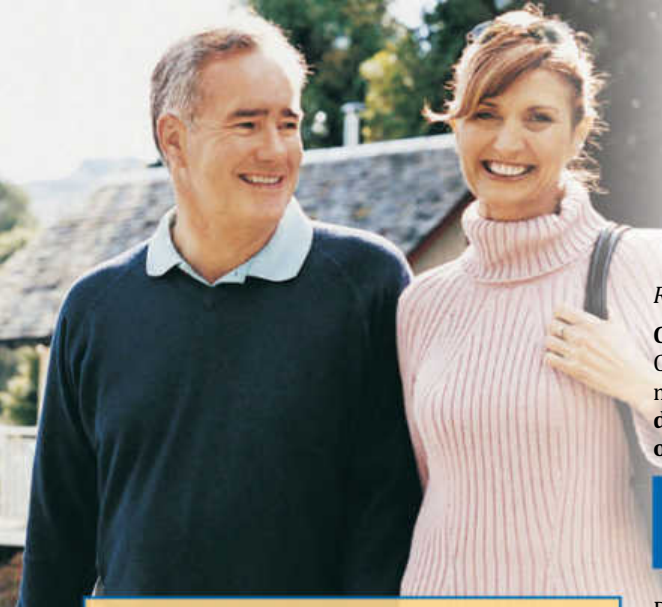
WEB

Blue Origin's Big Day

On Nov. 23, Jeff Bezos' private spaceflight company, Blue Origin, successfully launched and landed its New Shepard reusable rocket. The company's ultimate vision is to send wannabe astronauts 62 miles into suborbital space to get a taste of what real astronauts see and feel.

With the future of space tourism looking bright, we asked readers if they would buy a ticket to space once Blue Origin starts accepting passengers. Most readers embraced the spirit of adventure; others, not so much.

CLOCKWISE FROM LEFT: JAY SMITH; CSA-PRINTSTOCK/ISTOCK; BLUE ORIGIN



Chicago Doctor Invents Affordable Hearing Aid

Outperforms Many Expensive Hearing Aids

Reported by J. Page

CHICAGO: A local board-certified Ear, Nose, Throat (ENT) physician, Dr. S. Cherukuri, has just shaken up the hearing aid industry with the invention of a medical-grade, affordable hearing aid. **This revolutionary hearing aid is designed to help millions of people with hearing loss who cannot afford—or do not wish to pay—the much higher cost of traditional hearing aids.**

"Perhaps the best quality-to-price ratio in the hearing aid industry" —Dr. Babu, Board-Certified ENT Physician

Dr. Cherukuri knew that untreated hearing loss could lead to depression, social isolation, anxiety, and symptoms consistent with Alzheimer's disease. **He could not understand why the cost of hearing aids was so high when the prices of so many consumer electronics like TVs, DVD players, cell phones, and digital cameras had fallen.**

Since Medicare and most private insurance plans do not cover the costs of hearing aids, which traditionally run between $2,000 — $6,000 for a pair, many of the doctor's patients could not afford the expense. Dr. Cherukuri's goal was to find a reasonable solution that would help with the most common types of hearing loss at an affordable price, similar to the **"one-size-fits-most" reading glasses** available at drug stores.

He evaluated numerous hearing devices and sound amplifiers, including those seen on television. Without fail, almost all of these were found to amplify bass/low frequencies (below 1000 Hz) and were not useful in amplifying the frequencies related to the human voice.

Inspiration from a Surprising Source

The doctor's inspiration to defeat the powers-that-be that kept inexpensive hearing aids out of the hands of the public actually came from a new cell phone he had just purchased. **"I felt that if someone could devise an affordable device like an iPhone® for about $200 that could do all sorts of things, I could create a hearing aid at a similar price."**

Affordable Hearing Aid with Superb Performance

The high cost of hearing aids is a result of layers of middlemen and expensive unnecessary features. Dr. Cherukuri concluded that it would be possible to develop a medical-grade hearing aid without sacrificing the quality of components. The result is the **MD**HearingAid ***PRO***, under $200 each when buying a pair. **It has been declared to be the best low-cost hearing aid that amplifies the range of sounds associated with the human voice without overly amplifying background noise.**

Tested by Leading Doctors and Audiologists

The **MD**HearingAid ***PRO*** has been rigorously tested by leading ENT physicians and audiologists who have unanimously agreed that the **sound quality and output in many cases exceeds more expensive hearing aids.**

DOCTORS AND PATIENTS AGREE: "BEST QUALITY SOUND" "LOWEST AFFORDABLE PRICE"

"I have been wearing hearing aids for over 25 years and these are the best Behind-the-Ear aids I have tried. ***Their sound quality rivals that of my $3,000 custom pair of Phonak® Xtra digital ITE."*** —Gerald Levy

"I have a $2,000 ReSound® Live hearing aid in my left ear and the MDHearingAid in the right ear. ***I am not able to notice a significant difference in sound quality between the two hearing aids."***
—Dr. May, ENT Physician

- **Designed by a Board-Certified Ear, Nose, and Throat (ENT) Doctor**
- **Doctor-Recommended, Audiologist-Tested**
- **Thousands of Satisfied Customers**
- **Batteries Included! Comes Ready to Use**
- **Free Shipping Available**
- **FDA-Registered**
- **Save up to 90%**
- **100% Money-Back Guarantee**

MDHearingAid® PRO

www.MDHearingAid.com

PROUDLY ASSEMBLED IN THE UNITED STATES FROM DOMESTIC & IMPORTED COMPONENTS

BBB A+ RATING ACCREDITED BUSINESS

For the Lowest Price Call Today

800-873-0680

Phone Lines Open 24 Hours EVERY DAY

www.MDHearingAid.com

Use Offer Code CK44 to get FREE Shipping and FREE Batteries for a Full Year!

100% Money-Back Guarantee

45-DAY RISK-FREE TRIAL

What Killed America's Behemoths?

Scientists debate whether hunters or climate gave mammoths the cold shoulder.

The disappearance of mammoths and giant sloths has defied explanation since the turn of the 19th century, when Thomas Jefferson sent Lewis and Clark on an expedition to, among other things, find the lost megafauna in the heart of America. Many researchers have blamed the extinction of most large mammals on the hunting excesses of nomadic humans. But could a changing climate be the culprit? In Science Smackdown, we let experts argue both sides.

Maybe humans aren't to blame for the mammoth's extinction after all.

PETER V. BIANCHI/NATIONAL GEOGRAPHIC/GETTY IMAGES

Too Darn Hot

Hunt-crazy humans weren't the main cause, says geneticist Alan Cooper of the University of Adelaide in Australia. Severe climate change throughout the Late Pleistocene, going back at least 125,000 years, was "perfectly capable of causing major problems," he says. "Some extinctions occurred before humans even showed up."

In a paper in *Science* last summer, Cooper and colleagues show a strong statistical correlation between megafaunal extinctions and sudden warming events called interstadials. "The interstadials were the single biggest magnitude change in climate to have occurred in the past 2 million years," Cooper says. Temperatures could rise as much as 10 degrees Celsius over just a few decades. "That's going to cause a massive disruption to weather patterns and also vegetation. Just look at the smaller-scale changes we're making to the climate now and the concomitant storms, droughts and fires."

Making a Killing

Stuart Fiedel, senior archaeologist at the New Jersey-based engineering consulting firm Louis Berger, begs to differ. The data analyzed in Cooper's paper focus on North America and Eurasia, and is too limited geographically to exonerate humans, Fiedel contends.

"Some 50 genera vanished in South America between about 13,000 and 11,000 years ago," he says. "Very few, if any, extinctions occurred in Africa during the same interval, although there must have been analogous climate shifts." Fiedel says that's a big problem for Cooper, and good evidence for the so-called overkill hypothesis. "African animals were adapted to human predation pressure after 2 million years of hunting, but South American mammals had no previous experience of human hunting," Fiedel explains.

Even in North America, Fiedel says, Cooper's paper "obscures the extraordinary temporal clustering of extinctions — at least 17 genera, and probably 35 — at the time of human arrival." — JONATHON KEATS

DID YOU KNOW? **Using a new gravity field map of the ocean floor, researchers recently pinpointed the exact timing of the tectonic collision that produced Mount Everest and the rest of the Himalayas: 47 million years ago. Good luck fitting all those candles on the birthday cake!**

FREE
Awning Idea Kit and DVD

- Cool Shade in Seconds
- 99% UV Protection
- Great Relaxation and Entertainment Spot
- Exceptionally Affordable — Prices as Low as $499!
- Saves Energy, Helps Cut Air Conditioning Bills
- Motorized & Manual Models
- Easy to Use, Totally Retractable
- Screen Rooms
- Many Exciting Accessories
- Many Designer Color Choices
- Unsurpassed Quality
- 5-Year Limited Warranty
- No Risk Home Trial
- A Must Have for Decks and Patios

Learn how to transform an ordinary deck or patio into a beautiful, shaded outdoor room — a cool, protected retreat where you and your family will love to spend time.

SunSetter, the #1 best-selling awnings in America for over a decade, invites you to call, email, or send today for our **FREE Awning Idea Kit and DVD**. Discover how to outsmart the weather and protect your family while you turn your deck or patio into your favorite 3-season outdoor room — a lovely focal point of your home and a center for outdoor enjoyment.

A SunSetter puts you in control of the weather on your deck or patio. Relax and entertain outside anytime you want without worrying about hot sun, harmful UV rays or passing light showers. It can be up to 20° cooler under your awning! A SunSetter gives you far more cool shade and protection than a tippy patio umbrella — yet it's so affordable you'll wonder why you waited so long to get one. **Get your Free Idea Kit and DVD today.**

SunSetter® AWNINGS

Find out more with absolutely no obligation. Get your **FREE Awning Idea Kit and DVD** in any of 4 simple ways:

1. **Call Toll Free: 1-800-876-8060, ext. 31626**
   You can call 24 hours a day, seven days a week.
2. **Email to ideakit@sunsetter.com**
   Be sure to include your full name and mailing address.
3. **Go to www.sunsetter.com**
4. **By Mail:** SunSetter Products, Dept. 31626
   184 Charles Street, Malden, MA 02148. Be sure to include your complete mailing address and email address.

Nipping Bedsores in the Bud

This bandage detects dangerous tissue damage before it appears on the skin.

A bedridden patient complains of lower back pain. Within days, her skin's outer layer reddens with irritation until it blisters. Tissue begins dying, and eventually more skin layers are damaged, exposing fat, muscle and bone — the patient has a full-blown bedsore.

Bedsores, or pressure ulcers, affect over 2.5 million Americans, cost $11 billion annually and can lead to debilitating and deadly infections. But that could change, thanks to collaboration between University of California, Berkeley engineers and UC San Francisco doctors. The team created a "smart" bandage that detects skin tissue damage before it's visible.

Healthy cells have nearly impermeable membranes. But when a cell starts to die, its membrane deteriorates, allowing electrical signals to pass through. The researchers took advantage of this to map electrical changes that occur when healthy cells in tissue die.

This sensor uses gold electrodes to detect tissue damage at a cellular level and prevent bedsores.

They adhered a thin sheet of electrodes onto rats whose skin had been squeezed between two magnets to mimic pressure wounds. The researchers then discharged a tiny current between neighboring electrodes that could detect tissue damage based on how much of the current passed through the cells. A computer then displayed a two-dimensional map of the data.

In theory, doctors could place the bandage on areas that seem inflamed or that easily develop bedsores, like the tailbone and hips, and the researchers envision the information displaying on the bandage itself. But for now, they're conducting human trials.

"Ulcers can lead to death," says study lead author Sarah Swisher, a UC Berkeley doctoral student at the time and now an assistant professor of electrical and computer engineering at the University of Minnesota. "If doctors have the information early, they can intervene."

—AMY KRAFT

THIS PAGE: UC BERKELEY. OPPOSITE: NASA/JPL-CALTECH/MALIN SPACE SCIENCE SYSTEMS

WHAT THE...? It's the Curiosity rover on Mars, as seen in this selfie, August 2015.

An Energetic Solution

A boost to bacteria's metabolism could help thwart antibiotic resistance.

Metabolites like glucose and alanine can boost sluggish bacteria's energy to help them absorb antibiotics.

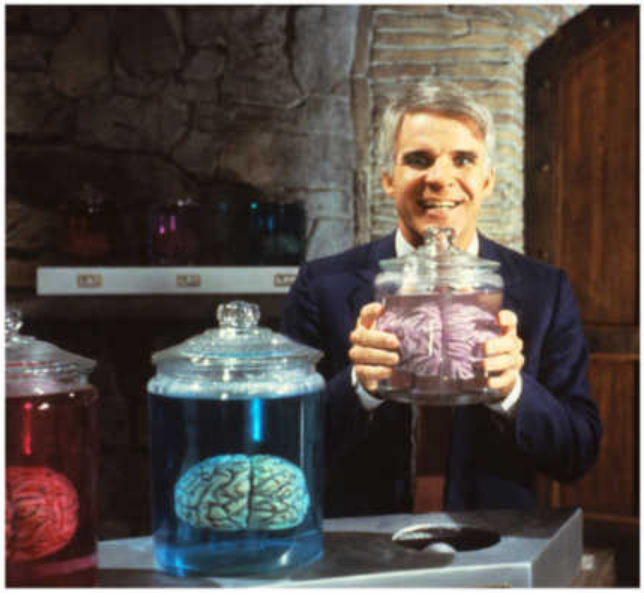
The fight against antibiotic resistance seems like an uphill battle: Bacteria outsmart our drugs, and our slow discovery of new antibiotics can't keep pace with their constant evolution. Although part of President Barack Obama's recent $1.2 billion allocation for fighting antibiotic resistance does involve drug discovery, some scientists and companies are repurposing existing therapies, which can save time and money.

For antibiotics to kill bacteria, bacterial cells must ingest them, and they need energy to do that. In 2011, James Collins, a systems biologist at the Howard Hughes Medical Institute, found that some bacteria unfazed by antibiotics are actually just less metabolically active than their sensitive counterparts and aren't energized enough to ingest the drugs. He called them persisters — different from genetically resistant bacteria that mutate to survive antibiotic treatment.

Many resistant bugs' mutations affect their metabolism, too. Fortunately, in the past five years, researchers discovered they can resensitize both persistent and resistant bugs to antibiotics. By combining the drugs with metabolites like alanine and glucose, the stubborn bugs increase their energy production and thus antibacterial uptake, which can boost the effects of antibiotics up to ten-thousandfold.

Now, these metabolite-antibiotic pairings are finally getting a test. In 2016, Massachusetts-based pharmaceutical company EnBiotix plans to launch clinical trials to assess the safety of two new combination therapies in patients. If the trials go well, says EnBiotix CEO Jeffrey Wager, it would mean saving $5 million to $7 million and two to three years in the FDA approval process compared with developing a new drug. Maybe then we'll have a chance to level the playing field and gain some ground in the fight against antibiotic resistance. —WUDAN YAN

Ask Discover



Q It's not uncommon to see the "brain in a jar" in TV shows or movies, but is it actually possible to keep a brain alive like that with modern technology?

— Vesta Moore, Lincoln, NE

A It's possible to keep an isolated brain alive, but only briefly. And for ethical and practical reasons, many experts steer clear of this scenario.

Scientists first kept a mammalian brain alive outside its body for about eight hours in the early 1990s. This and subsequent similar experiments used guinea pig brains because they're larger and easier to work with than mouse brains. But these mostly European studies set out to understand aspects of the whole brain, not to test how long it can survive separately. There's scant research that's similar in the United States, likely because of the dubious ethics involved in keeping an animal brain "alive" apart from its body.

A more realistic and ethical "brain in a jar" would be dead, but perfectly preserved. In 2015, scientists preserved a mouse's neural circuitry by chemically fixing the brain's fatty molecules and proteins in place and replacing the brain's water with plastic. This brain could sit on a shelf until technology has advanced enough for us to scan and re-create the neural network in a new robot body or virtual environment. It's a less nightmarish scenario than life in a jar for hundreds of years. —LEAH SHAFFER

Visit **DiscoverMagazine.com/Ask** for more. To submit a question, email us at **Ask@DiscoverMagazine.com**

LEFT: SEA WAVE/SHUTTERSTOCK. RIGHT: THE MAN WITH TWO BRAINS, STEVE MARTIN, 1983, WARNER BROS/EVERETT COLLECTION

To some, sunglasses are a fashion accessory…

But When Driving, These Sunglasses May Save Your Life!

Studies by the National Highway Traffic Safety Administration (NHTSA) show that most (74%) of the crashes occurred on clear, sunny days

Drivers' Alert: Driving in fall and winter can expose you to the most dangerous glare… do you know how to protect yourself?

In the fall and winter, the sun is lower in the sky so it rises and sets at peak travel periods. During the early morning and afternoon rush hours many drivers find themselves temporarily blinded while driving directly into the glare of the sun. Deadly accidents are regularly caused by such blinding glare with danger arising from reflected light off another vehicle or snowy and icy pavement. Yet, motorists struggle on despite being blinded by the sun's glare that can cause countless accidents every year.

Not all sunglasses are created equal. Protecting your eyes is serious business. With all the fancy fashion frames out there it can be easy to overlook what really matters—the lenses. So we did our research and looked to the very best in optic innovation and technology.

Sometimes it does take a rocket scientist. A NASA rocket scientist. Some ordinary sunglasses can obscure your vision by exposing your eyes to harmful UV rays, blue light, and reflective glare. They can also darken useful vision-enhancing light. But now, independent research conducted by scientists from NASA's Jet Propulsion Laboratory has brought forth ground-breaking technology to help protect human eyesight from the harmful effects of solar radiation light. This superior lens technology was first discovered when NASA scientists looked to nature for a means to superior eye protection—specifically, by studying the eyes of eagles, known for their extreme visual acuity. This discovery resulted in what is now known as Eagle Eyes®.

Slip on a pair of Eagle Eyes® and everything instantly appears more vivid and sharp. You'll immediately notice that your eyes are more comfortable and relaxed and you'll feel no need to squint. These scientifically designed sunglasses are not just fashion accessories for the summer; they are necessary to protect your eyes from those harmful rays produced by the sun in the winter.

The Only Sunglass Technology Certified by the Space Foundation for UV and Blue-Light Eye Protection. Eagle Eyes® features the most advanced eye protection technology ever created. The TriLenium® Lens Technology offers triple-filter polarization to block 99.9% UVA and UVB—plus the added benefit of blue-light eye protection. Eagle Eyes® is the only optic technology that has earned official recognition from the Space Certification Program for this remarkable technology. Now, that's proven science-based protection.

The finest optics: And buy one, get one FREE! Eagle Eyes® has the highest customer satisfaction of any item in our 20 year history. We are so excited for you to try the Eagle Eyes® breakthrough technology that we will give you a **second pair of Eagle Eyes® Navigator™ Sunglasses FREE—a $99 value!**

That's two pairs to protect your eyes with the best technology available for less than the price of one pair of traditional sunglasses. You get a pair of Navigators with stainless steel black frames and the other with stainless steel gold, plus two micro-fiber drawstring cleaning pouches are included. Keep one pair in your pocket and one in your car at all times.

Your satisfaction is 100% guaranteed. If you are not astounded with the Eagle Eyes® technology, enjoying clearer, sharper and more glare-free vision, simply return one pair within 60 days for a full refund of the purchase price. The other pair is yours to keep. No one else has such confidence in their optic technology. Don't leave your eyes in the hands of fashion designers, entrust them to the best scientific minds on earth. Wear your Eagle Eyes® **Navigators** with absolute confidence, knowing your eyes are protected with technology that was born in space for the human race.

Navigator™ Black Stainless Steel Sunglasses

Receive the Navigator™ Gold Sunglasses (*a $99 value*) **FREE! just for trying the Navigator™ Black**

Navigator™ Gold Stainless Steel Sunglasses

Certified EAGLE EYES® was developed from original NASA Optic technology and was recently inducted into the Space Foundation Technology Hall of Fame.

Fit-ons available for $39 +S&H
Black or Tortoise-Shell design

Eagle Eyes® Navigator™ Sunglasses ~~$99~~†
Offer Code Price **$49** + S&P **Save $50**
***PLUS* receive the Navigator™ Gold absolutely FREE!—2 pairs for the price of one!**

1-800-333-2045

Your Insider Offer Code: EEN288-02
You must use this insider offer code to get our special price.

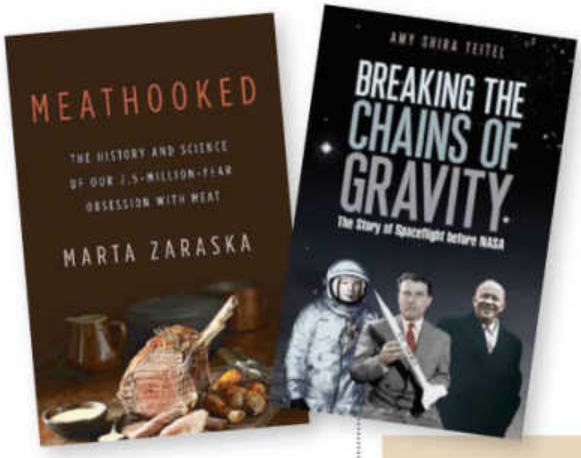
Stauer®

BBB ACCREDITED BUSINESS **Rating of A+**

14101 Southcross Drive W., Dept. EEN288-02
Burnsville, Minnesota 55337 www.stauer.com

† Special price only for customers using the offer code versus the price on Stauer.com without your offer code.

Smart Luxuries—Surprising Prices™



BREAKING THE CHAINS OF GRAVITY

THE STORY OF SPACEFLIGHT BEFORE NASA

By Amy Shira Teitel

Blogger and embedded NASA reporter Teitel opens her gripping history of leaving the planet (or trying to) with a bang — literally. She recounts the fatal lab accident that claimed early rocketry pioneer Max Valier in 1930 with an anecdote full of technical minutiae but taut with drama. It encapsulates Teitel's approach to the topic: an enthusiastic dive into detail that's accessible even to those of us happy to keep both feet firmly on the ground.

MEATHOOKED

THE HISTORY AND SCIENCE OF OUR 2.5-MILLION-YEAR OBSESSION WITH MEAT

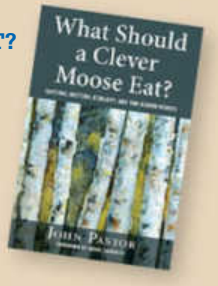
By Marta Zaraska

Do you suffer from "meat hunger?" You're not alone. Science writer Zaraska traces our affinity for animal flesh from the first species evolved to have a mouth (enabling it to eat other species — and its own) to superslick advertisements that make you crave bacon. Don't worry, vegans, there's something here for you, too: Zaraska suggests carnivory among humans may be rooted more in culture and myth than actual physiological need. Thought-provoking and enjoyable, it's a book you can really, ah, sink your teeth into.

OTHER PAGES WE'RE TURNING

WHAT SHOULD A CLEVER MOOSE EAT?

NATURAL HISTORY, ECOLOGY AND THE NORTH WOODS

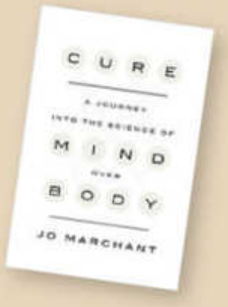


By John Pastor

Even if you've never been to the North Woods — the broad swath of continent stretching from the Canadian Maritime Provinces to the far shores of Lake Superior — you will come to appreciate it through ecologist Pastor. With an eye for fine detail and the gentle explication of a born teacher, Pastor crafts a rich biography of one of North America's most beautiful and diverse ecosystems, from the geology of its foundations to the birds in its skies.

CURE

A JOURNEY INTO THE SCIENCE OF MIND OVER BODY



By Jo Marchant

Each year Americans spend about $34 billion on alternative medicine, much of which fails to hold up under scientific scrutiny. But what if science was missing the point? With doctorates in genetics and microbiology, Marchant is no fringe thinker advocating quackery. Instead, with admitted skepticism, she explores a growing field of research into the mind's largely untapped power to heal the body.

WHY WE SNAP

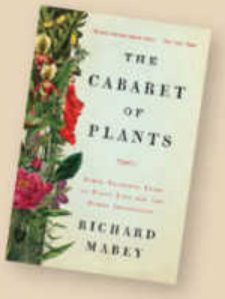
UNDERSTANDING THE RAGE CIRCUIT IN YOUR BRAIN

By R. Douglas Fields

National Institutes of Health neuroscientist Fields examines the triggers and pathways that can turn anyone into a killer — or a self-sacrificing hero — in the blink of an eye.

THE CABARET OF PLANTS

FORTY THOUSAND YEARS OF PLANT LIFE AND THE HUMAN IMAGINATION



By Richard Mabey

The latest tome from prolific nature writer Mabey tells the story of our relationship with plants — as food and medicine, as symbols and fashion statements — through fascinating vignettes of different species from the green kingdom.

— ALL REVIEWS BY GEMMA TARLACH

DID YOU KNOW? **Here's some shortsighted research: A meta-analysis of 15 European studies found that myopia is becoming more common on the continent. Risk for shortsightedness rises with education level, suggesting that reading and working with computers is a factor.**

The Spirit of the West Express-Silver Edition

Locomotive Lights Up!

Not Available in Any Store!

Celebrate the 100TH ANNIVERSARY of the Indian Head Nickel with this real working electric train collection.

Fine collectible. Not intended for children under 14.
Shown slightly larger than actual size.
Product does not include actual U.S. minted coins.

HAWTHORNE VILLAGE MASTERPIECE RAILWAYS®

Everything You Need to Run Your Train!

Along with Shipment Two, you will receive a 14-piece track set—creates a 47" x 38" oval—power-pack and speed controller—a $100 value—YOURS FREE!

Honoring the spirit of one of the world's most valued coins!

The Indian Head Nickel is considered one of the nation's most beautiful coins and is a favorite among collectors. Minted for only 26 years—from 1913 to 1938—the Indian Head Nickel is extremely rare. Only 1 in 25,000 nickels circulating today is of the Indian Head type. Highly sought and prized by collectors, some of these coins are valued in the six figure range.

Hawthorne is now proud to present the exclusive *Spirit of the West Express—Silver Edition* that celebrates the centennial of this treasured coin! This handsome silver tone train features sculpted raised relief throughout of Indian Head Nickels lavished with gold & turquoise tone flourishes. Plus there are dramatic golden scenes of Buffalo and Native Americans on the plains. And this train highlights the famous buffalo portrait found on the reverse design of the Indian Head Nickel. This is a must-have heirloom-quality train that runs on any HO-gauge track.

The Steam Locomotive's front boasts a raised relief Indian Head Nickel and a headlamp that shines a beacon of light as it powers along the tracks!

An incredible train at an exceptional value.

Begin with the illuminating "Steam Locomotive." It can be yours for three easy payments of $26.66*, the first billed before shipment. Subsequent shipments—each billed separately at the same low price—will be sent about every other month in addition to the track set, power-pack and speed controller that come FREE with Shipment Two—a $100 value! You may cancel at any time and our best-in-the-business 365-day guarantee assures your satisfaction.

Not available in any store! Order today!

Strong demand is expected. *Send no money now.* Just mail the Reservation Application today.

www.bradfordexchange.com/BuffaloTrain

LIMITED-TIME OFFER—RESPOND PROMPTLY

THE BRADFORD EXCHANGE
HAWTHORNE VILLAGE DIVISION

9210 Maryland Street
Niles, IL 60714-1322

YES! Please enter my order for one *Spirit of the West Express-Silver Edition* electric train collection, beginning with the "Steam Locomotive" as described in this announcement.

SEND NO MONEY NOW.

Signature _____

Mrs. Mr. Ms. _____
Name (Please Print Clearly)

Address _____

City _____

State _____ Zip _____

Email _____

Certificate of Authenticity and 365-day guarantee.

917930-E23601

*Plus $9.99 shipping and service. Please allow 4-6 weeks after initial payment for shipment. Sales subject to product availability and order acceptance.

Get That Song Outta My Head!

If a catchy tune gets stuck in your mind, don't worry; you're not just hearing voices.

BY **MICHELE WOJCIECHOWSKI**

The nightmare began when my husband walked into our kitchen and said, "I've had this song stuck in my head all day …"

No! I thought. *Don't say it!*

"Remember that song from the original *Karate Kid* movie?" he continued.

For the love of God, no!

"You know how it goes. 'You're the best around … na na na na na, na na na na. You're the best around …"

It was too late. Now I had an earworm — a song, melody or jingle that gets stuck in your head.

The worst part? I only knew that same line. I walked around humming it for days. I tried to shake it by singing along with tunes playing on my car radio while I was out running errands. For a brief time, Van Halen's "Runnin' With the Devil" replaced it.

But in no time at all, that one line from "You're the Best," sung by Joe Esposito on the *The Karate Kid* soundtrack, was back.

Perhaps if I heard more of the song in my head, it wouldn't be as annoying. But just this one line? Over and over and over again? It was pure torture. I needed to do something drastic. I busted out that 1980s hit, "The Safety Dance" by Men Without Hats. After singing it a few times, the earworm was gone.

I knew I'd get another one, though. About 90 percent of people experience earworms at least once a week, according to the Earworm Project run by the Music, Mind and Brain group at Goldsmiths, University of London.

"Music lovers, specifically people who ascribe more importance to music or people who spend more time listening to music, have more frequent and longer earworm episodes," says Kelly Jakubowski, a researcher with the Earworm Project.

Great. So all that singing I've done along with the car radio was coming back to bite me.

To find out what causes earworms and how to get rid of them, I contacted the man known as "Dr. Earworm," James Kellaris, a marketing professor at the University of Cincinnati. Certainly with a nickname like that, he would know something.

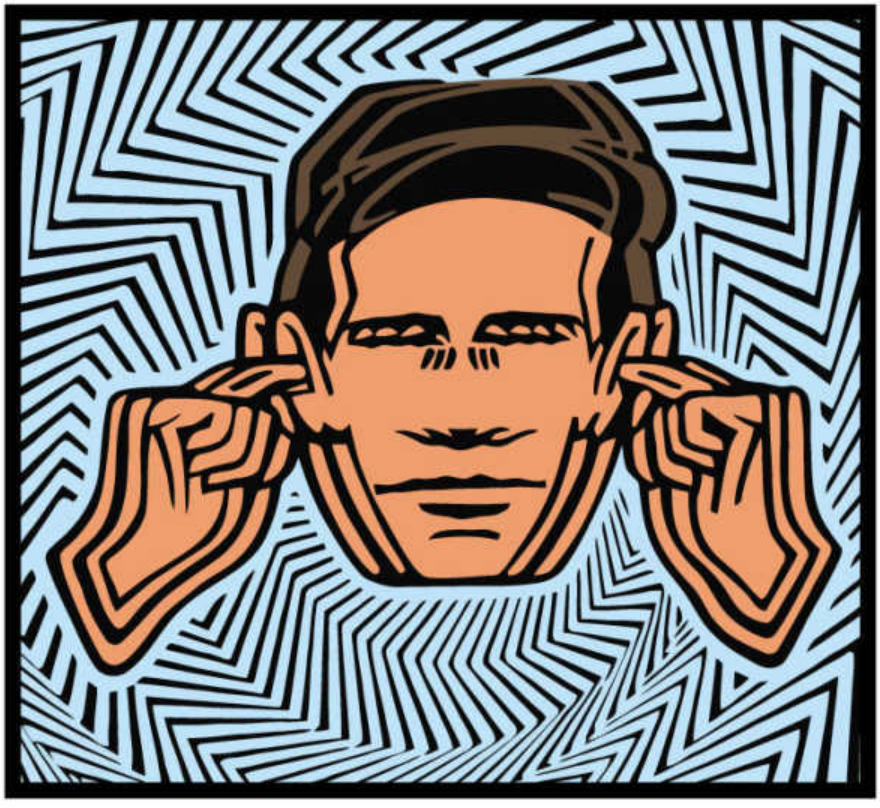
Kellaris began studying earworms in 1999. A former professional musician prone to getting earworms himself, he eventually became a marketing professor "interested in how marketers use music to achieve various commercial goals," he says. "It was a perfect storm to create an earworms researcher."

He explained to me that when we get an earworm, the tune seems to repeat itself involuntarily, which is why experts consider earworms involuntary musical imagery (INMI). This was exactly what "You're the Best" had done to me.

So what, precisely, was happening in my brain when I couldn't shake that tune?

WHAT'S GOING ON? (NO, NOT THE MARVIN GAYE HIT)

Jakubowski contributed to a May 2015 study led by Nicolas Farrugia, a postdoctoral researcher with the



ULTRAVIOLET/SHUTTERSTOCK

Earworm Project, that demonstrated auditory and inhibitory-related areas play a role in earworms as well.

The researchers examined 44 healthy subjects, all between 25 and 70 years old and all participants of a past neuroimaging study run by the Cambridge Medical Research Council's Cognition and Brain Sciences Unit. These subjects took an online survey that measured both the extent of their musical training and how strongly INMIs impacted them. For example, the survey wanted to know how strong of a negative impact INMIs had on them or if INMIs were actually helpful while they went about their everyday activities.

When they examined these participants' brain images, one pattern in particular stuck out: People who got earworms more often had a thinner right frontal cortex, which is involved in inhibition, and a thinner temporal cortex, which processes sensory stimuli like sound. In other words, these people's brains just weren't as good at suppressing the random song that might pop into their heads.

Why we get earworms, unfortunately, remains a scientific mystery. "We know that songs that are 'catchy' — short, simple, repetitive and contain some incongruity — are most likely to get stuck," Kellaris says. Most people are more likely to get a song like "Don't Worry, Be Happy" stuck in their heads than, say, a Mahler symphony. And some things exacerbate them: frequency and duration of exposure to music, worry, stress, fatigue and idleness.

Considering that my husband kept singing the snippet while I was tired and stressed, I can see why it got stuck. But my earworms have been relatively innocuous. Even though they're annoying, I can eventually get rid of them. Some people can't, though.

Part of Kellaris' earliest research involved mailing a questionnaire to about 1,000 respondents at four U.S. universities. He asked them if they'd ever had an earworm, for how long, how often it happened, how it made them feel, etc.

One respondent claimed to have had a song stuck in his head since 1978. This is known as intrusive musical imagery (IMI), a musical obsession that's chronic and highly distracting to a person's everyday life and work. According to Dean McKay, a psychology professor at Fordham University, my short-lived earworm was nothing compared to an IMI.

"We know that songs that are 'catchy' are most likely to get stuck," Kellaris says. Most people are more likely to get a song like "Don't Worry, Be Happy" stuck in their heads than, say, a Mahler symphony.

But now I was concerned. Could my future earworms turn into these IMIs? Is there a way to prevent this from happening?

DOCTOR, DOCTOR, GIVE ME THE NEWS

McKay co-authored a June 2014 study titled "Musical obsessions: A comprehensive review of neglected clinical phenomena." For this study, McKay and other international colleagues, all of whom treat obsessive-compulsive disorder, created the first comprehensive review of musical obsessions. They compiled a database of 96 case study descriptions of people with severe musical obsessions — the largest compilation assembled on this topic. They determined the characteristics of musical obsessions such as IMIs and compared them with earworms, musical hallucinations and visual obsessional imagery.

The group's research showed that IMIs can be treated by using a method known as distraction — coming up with a competing melody to think about that would get rid of the IMI. That's exactly what I had done, albeit unknowingly, when I used "The Safety Dance" to stop my earworm.

McKay says my earworm was pesky because I knew only that one part of the song. He suggests if I have just a portion of a song looping in my brain in the future, I can try another method called exposure — simply listening to the entire song. "It's like a completion task," he says. "Once you know the whole song, then there's no need for it to be stuck in your head."

Another form of distraction is to sing the song out loud, but change some of the words or slightly throw off the melody. One of McKay's patients had an IMI based on a Taylor Swift song. "We made up some other words for it," he explains. "We messed up the melody a bit, but not so much that it wasn't recognizable as still being that song, and then it faded." McKay stresses that this is the only case he's tried this in, so it's not a forgone conclusion this kind of distraction would work in other instances.

What I wanted to know was if the earworm I get today could become the IMI of tomorrow.

"Highly improbable," he says.

"You're the best," I reply.

Oh no. D

Michele Wojciechowski *is the author of the award-winning humor book* Next Time I Move, They'll Carry Me Out in a Box.

LEFT: MARK SULLIVAN/CONTOUR BY GETTY IMAGES. RIGHT: PETER STILL/REDFERNS/GETTY IMAGES

A Change of Mind

How did this 30-something guy go from charismatic to catatonic? A trip down memory lane will get you there.

BY **ELIEZER J. STERNBERG**

When I first met Billy, he was sitting motionless in a wheelchair, gnawing on a bedsheet dangling from the side of his mouth. He did not reply to questions. When I asked him something, he would just stare at me with an ear-to-ear smile, as if he knew something no one else did. His muscles were stiff. Occasionally he would glance from side to side, chew on the sheet or pick at his arms with his fingernails.

Two weeks ago, Billy went to the emergency department of another hospital with wet shoes on the wrong feet, saying, "I need to talk … about brain damage." Now he was in a state of catatonia, immobile and stuporous. How could a perfectly healthy guy become like this in just a handful of days?

With silky black hair, a winning smile and a cocky, sarcastic edge to his humor, Billy typically had enough charm to fill any room and made friends easily. He was in his early 30s, had a master's degree in chemistry and worked for years in a commercial laboratory. He was moving up in his career and had a steady girlfriend.

But suddenly things changed. He became distant from his friends and family. He was laid off from his job and broke up with his girlfriend. He lost the ability to pay his bills, maintain his car and apartment, and feed himself. When his mother went to look for him in his apartment, she discovered towering stacks of empty pizza boxes. Full, untouched containers of home-cooked food she'd made for him lay all over the house, spoiled. Billy's car was found abandoned in a distant public park. No one was sure how he found his way to a hospital. The answers would have to come from Billy, but he was mute.

LOST MEMORIES

After being transferred to our hospital, Billy went straight to the psychiatric ward, where we immediately asked the question: What caused him to become catatonic? Catatonia can result from severe infections, medication side effects or drug overdoses, or it can be a complication of psychiatric illnesses, like bipolar disorder or schizophrenia. Since Billy did have bipolar disorder, we identified that as the likely culprit, though Billy's mother insisted that his case was a mild one.

We started with a drug screen, which came back clean for illicit substances. Routine blood tests were normal. A CT scan of his brain was normal; an MRI was equally inconclusive. Yet, the catatonia had to be treated, even if we couldn't be sure what caused it.

While it's been misused in the past, the best-known and scientifically proven treatment for catatonia is electroconvulsive therapy (ECT). It involves inducing 30-second-long seizures by firing electrical pulses at the brain under general anesthesia.

We decided to try it with Billy, and the results were incredible. After several sessions over a handful of days, the catatonia began to regress, and Billy's personality started to re-emerge. He began talking again — a lot — though much of what he said was initially incomprehensible. He started flirting with female nurses and doctors, giving them an occasional wink or asking them out on dates. His sense of humor returned, and, after a few weeks of treatment, Billy could walk without a wheelchair. One thing, however, did not return to normal: his memory.

Billy could not remember basic information about himself or his past. He could not recall who the president was, who his doctor was, or even that he was in a hospital. Yet, he always pretended he knew the right answers.

"Billy, do you know why you're here in the hospital?" I asked.

"Yeah, because of my knee."

"What's wrong with your leg?"

"It's been hurting me for weeks. That's why I got surgery on it yesterday."

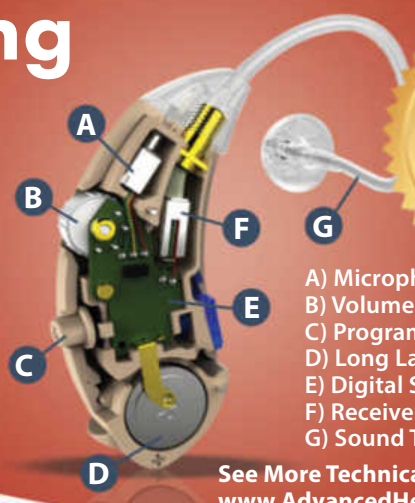
This wasn't true, of course. "You got surgery yesterday?"

"Yeah," Billy nodded. "It was a torn ligament. Surgery went well, though. You guys have been great at taking care

68/COLIN ANDERSON/OCEAN/CORBIS

Affordable Hearing Aid Technology Only $299!

Learn about our great digital technology at an affordable price.



FREE 1 YEAR Supply Of Batteries*

A) Microphone
B) Volume Control Wheel
C) Program Button
D) Long Lasting Battery
E) Digital Signal Processor
F) Receiver (Speaker)
G) Sound Tube

See More Technical Information At: www.AdvancedHearing.com/D63

The Revolutionary HCX!

- Digital sound processing chip provides **crystal clear sound and makes speech easier to understand** without feedback
- Multiple memory programs **adapt to most listening situations**
- Nearly invisible thin tube design
- Long lasting size 13 batteries and a **low battery warning**
- 10 bands of layered noise reduction helps to **emphasize voices while balancing out background noise**
- **100% Money Back Guarantee**

5 Star Reviews! ★★★★★

Wonderful Company! "I will definitely recommend your company to my patients." - **Dr. Arun P.**

They Are Fantastic! "I just received my HCX hearing aids and they are fantastic. Advanced Affordable is far superior and far more affordable!" - **Chuck D.**

Studies Show That Hearing Aids May Help Prevent Dementia.

A study by Dr. Frank Lin at John Hopkins University, found that adults with hearing loss are significantly more likely to develop dementia and at a faster rate. Fortunately, the use of hearing aids is an effective way to treat hearing loss and may help you maintain healthy mental activity.

Read More Information At:
www.AdvancedHearing.com/Dementia

Digital Hearing Aid Technology... For Only $299!

All hearing aids work the same way. The **microphone** picks up the sound and sends an electrical signal to the digital signal processor. The **digital signal processor** is the "brains" of the hearing aid. It takes the sound it receives and adjusts the sound to amplify important speech sounds as well as filtering out unwanted noise. (To ensure the best in quality, our digital processor is designed and manufactured right here in the **United States.)** Once the processor has amplified the sound, it is passed to the **receiver** (also known as the speaker) which emits a corrected and amplified sound through the **sound tube** into your ear.


The HCX™

Most importantly, your new HCX hearing aids work at a **fraction of the cost** of name-brand hearing aids. In addition to the technical components of the hearing aid, you also have a **volume control** that can be modified with a light touch of the finger. Your new hearing aids come with **3 different audio programs** that help you listen in different sound environments. You will love the Open-fit design, that is so light you probably won't even feel that you are wearing your hearing aids – you'll just be hearing clearly!

You can spend thousands for a high-end hearing aid or you can spend **just $299** for a hearing aid that just plain works **(only $279 each when you buy a pair)**. We are so sure you will love our product, that we offer a **100% Money Back Guarantee - Risk Free** if you are not satisfied for any reason. It's time to get great digital technology at an affordable price!

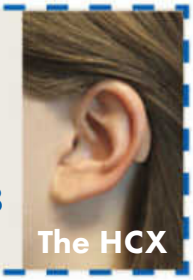
BUY A PAIR AND SAVE $40!

888-291-3810

Free 1 Year Supply Of Batteries!

*Use Coupon Code When You Order: **D63**

(Coupon Code & Price Valid For A Limited Time Only!)


The HCX

Advanced Affordable Hearing
Affordable Quality Since 1996!

A+ BBB ACCREDITED BUSINESS

100% MONEY BACK GUARANTEE

RISK FREE Trial

US Company Owned And Operated

FDA REGISTERED

Visit and Save: **www.AdvancedHearing.com/D63**

of me. I can walk a lot better now. No wheelchair or anything."

His answer referenced the fact that he had recently been using a wheelchair, but the rest of his story was false. Yet Billy wasn't intentionally lying. He was exhibiting a symptom known as confabulation, in which patients cover up gaps in memory by fabricating bogus replies and asserting them with confidence. Each morning I would interview Billy, asking any and all questions that came to mind as I tried to uncover clues that might hint at what caused his sudden transformation. Each time he would trot out the same confabulated answers. As days turned into weeks, Billy just wasn't getting better.

"NEVER SEEN ANYTHING LIKE IT"

When physicians see new symptoms develop in the hospital, we always have to wonder: Is it something we did? Doctors wonder about medication side effects. Surgeons fear complications. In our case, we had fired electrical shocks at Billy's brain in an attempt to cure his catatonia. But could that have disrupted his memory? Absolutely. Memory loss is a known side effect of ECT, though it is usually transient. In rare cases, however, the damage to memory can endure for months or even years.

At what point do you attribute a devastating symptom to a treatment's side effect? When you've exhausted all the other possibilities. We decided to send Billy through the MRI machine for a second scan of his brain. If there was damage, perhaps now it would reveal itself.

I opened the MRI image file, Billy's gray and white matter overtaking the computer screen. The scan was abnormal, but I couldn't say how. I called the neuroradiology department.

"Yes, I'm looking at it now," the radiologist said. "It's hard to say. There's diffuse damage there, especially in the deep recesses of the brain. I am just not sure what could cause this. The pattern is very strange. I've never seen anything like it."

The damage was widespread, perhaps consistent with a large-scale injury such as a stroke or inflammation. Yet, the outcome on Billy himself was so isolated, so specific. Only his memory was affected. It just didn't make sense.

THE ART OF SELF-EXPRESSION

I was nervous. It was nearly two months into Billy's hospitalization, and his mother was coming in for a meeting. She wanted answers, and she deserved them. Billy hadn't made any progress. The tests we had done were confusing. The account of the events leading to his hospitalization remained as cloudy as ever. We were stumped.

Billy, however, was as jovial as ever, unaware that he was a walking medical mystery. He was equally unaware that he would be the one to solve it. After lunch, Billy joined some other patients who were participating in a group activity in which everyone was supposed to draw some of their favorite things. Self-expression, the instructor said, is an essential part of healing. Art therapy also can help tap memories that otherwise are locked away.

"I'm going to draw my favorite chemical reaction!" Billy exclaimed. Since he had worked in a laboratory for years synthesizing chemical compounds, this seemed like a reasonable thing for him to do. He sketched something on a sheet of notebook paper.

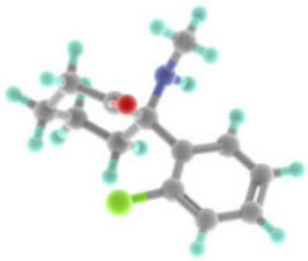
It appeared to be a partial sketch of a chemical reaction. Seeing the drawing, one of the medical students became curious. "What have you drawn there, Billy?"

"It's the reaction to make ketamine. It's nearly there. I just have to make a few adjustments. I used to make it in the lab."

"Why did you decide to draw that?"

"It was fun. Great for parties. I used to eat it all the time."

I didn't know much about ketamine, so I immediately began investigating it. Ketamine — its street name is "special K" — is used as short-term anesthesia for brief surgical procedures. Recreationally, it's known as a date-rape drug because it's virtually undetectable if you were to put it in someone's drink. It causes confusion and loss of inhibitions, followed by short-term memory loss. Routine drug screens can miss it. Apparently, years of ketamine abuse can wreak havoc on the brain and cause catatonia as well as severe memory deficits and confabulation.



Billy was diagnosed with acute toxic encephalopathy, loosely translated as "drug-induced brain fry."

Billy was diagnosed with acute toxic encephalopathy, loosely translated as "drug-induced brain fry." He gradually improved month after month. The last time I saw him, his memory was much better, and he was well on his way to recovery. He put his hand on my shoulder, looked me squarely in the eyes and said, "Hey man, I'm gonna give you some sound advice: Stay away from ketamine."

Good advice. I just hoped he would remember it. D

Eliezer J. Sternberg *is a resident neurologist at Yale-New Haven Hospital. This piece is adapted from his most recent book,* NeuroLogic: The Brain's Hidden Rationale Behind Our Irrational Behavior. *The cases in Vital Signs are real, but names and certain details have been changed.*

PASIEKA/SCIENCE SOURCE

2016
Silver American Eagles

image is for representation only

Beat the Rush!

First Time Offered • Order Today

- ★ **SPECIAL PRICING**
- ★ **HIGH DEMAND, Strictly Limited Inventory**
- ★ **IRA APPROVED,** 1 oz. of .999 Fine Silver
- ★ **GUARANTEED & BACKED** by the U.S. Government
- ★ **GEM BRILLIANT** Uncirculated Condition

Five Reasons To Order Now!

1. The U.S. Mint may stop producing or selling 2016 Silver Eagles at any time just like the recent 2015 Silver Eagle sales suspensions!
2. Global economic uncertainty could send silver prices dramatically higher at any time, power boosting demand for these coins and limiting their availability to you.
3. 2016 Silver American Eagles are not only a solid silver purchase, but they are also a true heirloom piece of American history to be enjoyed in your family's estate for generations to come.
4. 2016 Silver American Eagles can never be worth less than their legal tender face value, or the price of silver, and are always worth more to collectors.
5. Silver Eagles are the most popular 1 ounce pure silver coins in the world.

FREE SHIPPING

Free Priority Shipping & Insurance
First 100 Orders ($6 Value)

As low as

$2.80 each over spot price* (check/wire price)

Phone Orders Only

1.800.321.8700

Vault Verification: **NDSCVRS0116**

Offer Expires: **03/03/16**

Check or Money Order

Availability not guaranteed • Price subject to change
Limit 5 per household • No Dealers Please

Silver: Price Example	If silver spot price at time of order is	plus	Special Offer Over Spot Price	equals	cost per coin (example only)
	$14.00	+	$2.80	=	$16.80

ORDER DELIVERY NOTIFICATION

Please note this is a Pre-Sale item and is expected to ship on or around January 22, 2016. The exact delivery date is dependent on the Unites States Mint meeting the anticipated production schedule. Prices are subject to change in response to market conditions. Ordering Pre-Sale items will delay shipping your entire order. If you wish to order other items and have them shipped separately, please place a separate order.

ASK US

When you call, ask how smart investors are maximizing their investment by building sets of gold and silver American Eagles today! 1.800.321.8700.

COMPARE & SAVE!

Call for GREAT QUANTITY PRICING, availability and payment terms on popular gold & silver bullion products, or visit us online at 1stNationalReserve.com

- ✓ **Shopping & Special Offers**
- ✓ **Award-Winning Videos & Resources**
- ✓ **Buying, Selling & Security tips and more**

***Spot Price- the daily quoted market price of precious metals in bullion form. Spot price determined solely by 1st National Reserve® at time of transaction. Please read important customer disclosures on our website or that accompany products purchased, including arbitration agreement.**

A+ Rating | BBB ACCREDITED BUSINESS Since 2002

1stNationalReserve.com® Est. 1989

We Support ICTA — Your Industry Watchdog | NGC Numismatic Guaranty Corporation Authorized Dealer

Rethinking Our Roots

For decades we focused on East Africa as our likely ancestral homeland. But should we be looking to the south?

STORY AND PHOTOS BY **RUSS JUSKALIAN**

South Africa is home to some of science's most recent and thrilling hominin fossil finds, including that of *Australopithecus sediba*. The species, discovered in 2008, is known from several specimens, including the hand of a female (left) and this skull of a young male researchers named Karabo.

If you want to explore our origin story, keep an eye out for the white stinkwood trees. That, at least, is what paleoanthropologist Christine Steininger says as we push our way up a gentle incline covered in waist-tall, brown and green grasses near Maropeng, a town about 45 minutes from Johannesburg, South Africa.

The land here is arid and open, except for hardy stinkwood and wild olive trees, which cling to existence in small patches. Their survival depends on putting down roots deep enough to sup on what little water collects in scattered depressions and crevices — the same spots where the fossils of our earliest ancestors have been found.

At South Africa's Cooper's Cave, rocks are thick with hominin fossils waiting to be studied (left and right). Paleoanthropologist Christine Steininger, at the nearby Swartkrans site (center), explains that the area's abundance of fossils may be due to predators, such as ancestors of today's leopards, dragging their kills up trees. As they ate, the bones fell into the caves.

Indeed, at the first stand of trees is a fissure so thick with fossils that they protrude from the breccia, a type of conglomerate rock, in cartoonlike abundance. There's enough material here for generations of scientists to excavate, says Steininger. And yet this particular trove is but one of a number that make up what is perhaps the most important network of early hominin sites anywhere on the planet.

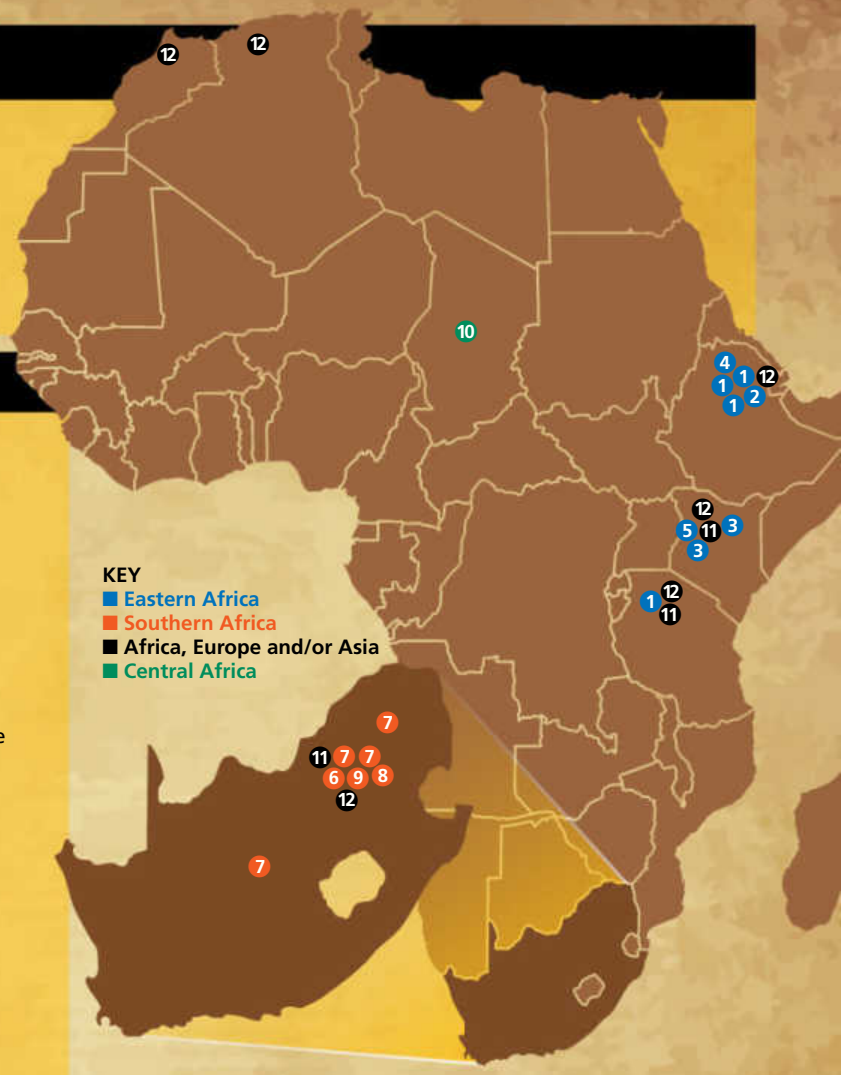
Covering an area more than twice the size of Brooklyn, the grasslands contain hundreds of complex dolomite caves, and more than a dozen early hominin dig sites with names like Sterkfontein, Swartkrans and Kromdraai. A UNESCO world heritage site since 1999, its name is fitting: The Cradle of Humankind.

Roughly 25 miles north of Johannesburg, The Cradle is a paradox of easy access and scientific significance but limited recognition among average citizens worldwide. You've probably heard of Ethiopia's famous fossil hominin Lucy, but what about South Africa's equally important Little Foot?

That disparity is about to change. The Cradle and other South African sites have ushered in a new golden age of discovery about our origins. Everything, from when our ancestors first commanded fire to the very shape of our family tree, is being challenged. The result: new species, new hypotheses and new controversies emerging from the deepest recesses of South Africa's cave-strewn landscape.

The Cradle Question

The hominin fossil record is sparse and incomplete, leaving relationships between species open to interpretation. That's especially true in Africa, where hominins first evolved. Both eastern and southern Africa have been touted as the birthplace of our extended family. With each new fossil found, however, our family picture becomes increasingly diverse, and our own lineage less certain. —GEMMA TARLACH



Eastern Africa

1 Australopithecus afarensis
(including the famous "Lucy")
Laetoli, Tanzania; sites in Ethiopia's Afar region include Hadar and Dikika
2.9-3.8 million years ago
(Lucy is 3.2 mya)

2 Australopithecus deyiremeda
Afar region, Ethiopia
3.3-3.5 mya

3 Australopithecus anamensis
Kanapoi and Allia Bay, Kenya
3.9-4.2 mya

4 Undescribed Homo
(species as yet unnamed)
Ledi-Geraru, Ethiopia
2.8 mya

5 Kenyanthropus platyops
Lake Turkana, Kenya
3.2-3.5 mya

Southern Africa

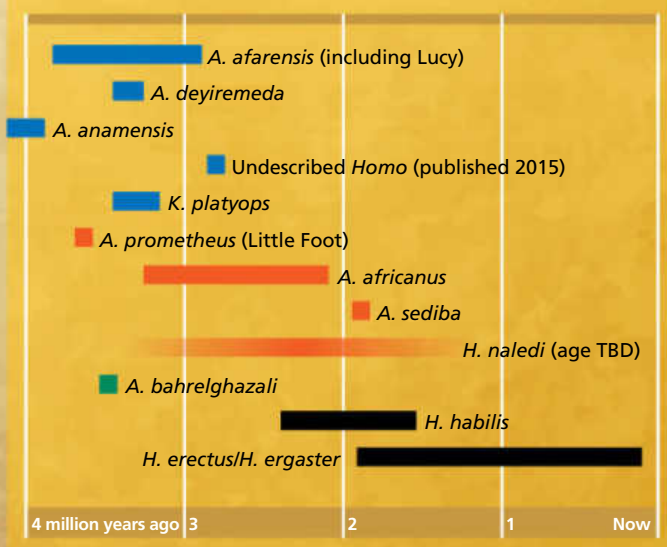
6 Australopithecus prometheus
(including "Little Foot")
Sterkfontein
3.67 mya

7 Australopithecus africanus
Taung, Sterkfontein, Makapansgat, Gladysvale
2.1-3.3 mya

8 Australopithecus sediba
Malapa
1.98 mya

9 Homo naledi
Dinaledi Chamber, Rising Star cave system
Age not yet determined

Timeline



Other Key Finds

10 Australopithecus bahrelghazali
Central Africa
Koro Toro, Chad
3.58 mya

11 Homo habilis
Olduvai and Koobi Fora (east); Swartkrans (south)
1.5-2.4 mya

12 Homo erectus/ Homo ergaster
Africa, Europe, Asia
African sites include Turkana, Olduvai Gorge and Bouri (east); Swartkrans (south); Ternifine and Sale (north)
150,000(?)-1.9 mya

DAN BISHOP/DISCOVER. BACKGROUND: HORENKO/SHUTTERSTOCK; MAP: STEFAN ALFONSO/ISTOCK

STERKFONTEIN

Prometheus Rises

The Silberberg Grotto at Sterkfontein Cave is locked behind a heavy gate. It's accessible via a circuitous, subterranean trek of dank tunnels and oversize ladders of the sort prospectors used during the California gold rush. It was here, sometime in the 1920s or early '30s, that a miner blasted apart breccia to dislodge chunks of valuable calcium carbonate that could be sold to local limeworks. Some of the discarded refuse — studded with fossils — found its way into boxes and sat mislabeled as antelope and monkey bones for the better part of a century.

Poking through one of these boxes in the 1990s, paleoanthropologist Ron Clarke found something peculiar: small, humanlike ankle bones. Surprised by the discovery, he sent two of his assistants on a near-impossible quest: "Go into the cave with torches," Clarke recalls telling them, "and see if you can find anywhere [this fits]."

On the second day, they found the spot. But excavating the fossils from the concretelike breccia was not a quick process. Only now, nearly two decades since digging began, is Little Foot — named for those initial small foot bones — being fully assembled.

The result is stunning: Among australopiths, the hominins immediately ancestral to our own genus *Homo*, Little Foot is by far the most complete specimen ever found. Photos of its fossilized skeleton look more like a modern forensic scene than something that's been locked underground for millions of years.

Much of what we know of human evolution comes from fragments and incomplete fossils, opening the door to misinterpretation. By contrast, the completeness of Little Foot's skeleton means we're more likely to gain a fuller understanding of its species, as well as where it fits in our family tree. Clarke has described its mix of ancient and modern body parts: hands with short palms and fingers like our own, a big toe that could grasp like an ape's, widely spaced eye sockets and large, bulbous molars. Adds Clarke: "The legs are definitely longer than the arms, not the other way around." Little Foot was made for walking upright, and it didn't drag its knuckles.

Perhaps the most striking thing about Little Foot came to light only last year: It's 3.67 million years old.

One of several mouths leads to the extensive Sterkfontein cave system (above), one of the world's richest hominin sites. Researchers continue to excavate fossils alongside public tours (below, background).

Paleoanthropologist Ron Clarke pieced together Sterkfontein's most famous find, which he dubbed "Little Foot" (above and above right). It's a game of chutes and ladders (far right) to reach the cave system's Silberberg Grotto, where Little Foot was found. Excavations continue in nearby Jacovec Cavern (right) where researchers believe they may find sediment even older than the 3.67-million-year-old rock encasing Little Foot.

Until Little Foot was found, the earliest hominin species known in South Africa was *Australopithecus africanus*, which is generally believed to have lived between 2 million and 3 million years ago. Many anthropologists have argued that *A. africanus* couldn't be our direct ancestor largely because of timing: The earliest known members of the genus *Homo* — though their classification remains controversial and their fossils fragmentary — turn up in East Africa soon after *A. africanus* appears in South Africa. This suggested that *A. africanus* was a parallel evolutionary line to our own, and that some other species gave rise to the line that eventually became human. For decades, before the diversity of early hominids in Africa became apparent, many researchers believed that humanity's most likely direct ancestor was East Africa's *Australopithecus afarensis*, best known through the famous 3.2-million-year-old Lucy.

Clarke argues that Little Foot, which he classifies as *Australopithecus prometheus*, represents a more primitive, separate species from *A. africanus*. And Little Foot's recently established age, making it contemporaneous with *A. afarensis*, raises questions about whether Lucy really was ancestral to us — or merely a distant cousin.

There's an even more complicated possibility. "It may be that these fossils that we're finding now, these hominids, had descendants that became extinct," says Clarke, "and that we haven't yet found the direct lineage of our ancestry."

MALAPA

Everything Up for Question

Less than 10 miles from Little Foot's Sterkfontein, a site called Malapa sits on a hillside of scraggly acacia trees that are stalked by a resident leopard. It was here in 2008 that Matthew Berger, the young son of American paleoanthropologist Lee Berger, found a fossilized clavicle sticking out of a rock. The discovery would shake up the world of paleoanthropology.

As the elder Berger and his team excavated, they were shocked to uncover a fairly complete australopith skeleton. Then another. Then parts from four more.

Finding a new dig site with such a dense cache of fossils was a surprise. "Up until that point, you have to remember, on the continent of Africa, no one had ever found two skeletons — and suddenly we were finding more," says Berger. In fact, prior to Malapa, so few new sites had been found in Africa that in 2000, at least one leading paleoanthropologist suggested that the field might as well stop looking.

Another surprise: The skeletons — with a mosaic of modern and ancient anatomy — represented a new species. Dated to around 2 million years, the individuals at Malapa were classified as *Australopithecus sediba*. The holotype specimen, used to describe the species, was a juvenile male given the name Karabo.

Once reconstructed, it was clear that Karabo had arms suitable for climbing and a brain not much larger than a chimpanzee's. But his teeth and hips were much like our own, his hands capable of tool-making. He also had a unique, hyperpronating way of walking unlike anything seen before. Karabo's anatomy was so peculiar that, had the skeleton not been found all at once, paleoanthropologists might have thought its various parts came from different species altogether.

"The foot had more primitive features than other hominids we think are primitive to this. The heel is chimpanzeelike," says Berger. "That's a problem. Because if you look at *afarensis*, Lucy's species, that's got a heel that's like a modern human's."

"You have to start driving uncomfortable questions," Berger says, "like maybe it's coming from something we haven't seen. Maybe there are other lineages out there." Like Clarke, Berger believes the labels on the tree of human evolution could be wrong because we haven't found all the species, or branches, that make up the tree. We may have attached evolutionary branches in the wrong places, building false relationships between species that didn't give rise to one another.

Even more tantalizing were the results of a recent meta-analysis using 13 datasets, composed of 20 previously described hominin species and their fossils, and covering all 7 million years of human evolution. The study found Karabo most likely to be ancestral to the genus *Homo* — but not a descendent of *A. africanus*. The research, focusing on cranial and dental features, was the first of its kind to compare competing hypotheses on the relationships between various hominin species using a complex method known as Bayesian analysis. Despite the results, however, the issue of timing complicates our understanding: While Karabo was estimated to be living shortly before fossils of *Homo* show up in South Africa, there are *Homo* fossils in East Africa that precede it by hundreds of thousands of years.

A. sediba remains an enigma. Karabo could be the last australopith before *Homo*, or a species that evolved after the *Homo* lineage split from the australopiths, similar to the relationship between us and our Neanderthal cousins. It could even be a late version of *A. africanus*.

Most disruptive of all is the suggestion that not all the species grouped within our own genus are necessarily from a single lineage — or that, perhaps, some of the species considered *Homo*, such as *Homo habilis*, are really australopiths.

Known as MH2, a partial skeleton was among several *A. sediba* specimens found in 2008 (above). The first bones were found by Matthew Berger, the young son of paleoanthropologist Lee Berger, who joined his father at press events touting the find (below left). A viewing platform now allows the public to see Malapa, the excavation site (below right).

FAR LEFT: FOTO24/GALLO IMAGES/GETTY IMAGES

WONDERWERK AND KATHU

Behavioral Clues

Just over 300 miles southwest of The Cradle, in South Africa's Northern Cape province, is the country's middle of nowhere, on the edge of the Kalahari Desert. It's a land covered in giant iron-ore mine dumps that resemble mountains. The area also hosts a remarkable collection of early hominin artifact sites, which are in danger of being damaged or destroyed by the extraction industry's boom and attendant economic activity.

The density of stone artifacts in the region is staggering. At a site called Kathu Townlands, beautiful, teardrop-shaped Acheulean-style hand axes, possibly dating to around a million years old, litter the ground. Three miles down the road, behind the parking lot of a rental car company and within frightening proximity of heavy mining trucks, is the equally important Kathu Pan dig site. Here, researchers have found Fauresmith stone blades — longer and narrower and more advanced than Acheulean axes — that are around 400,000 to 500,000 years old, nearly twice the age of those found anywhere else on the planet. This raises questions about which of our ancestors created such advanced tools so early. Did the human way of life arrive suddenly with modern *Homo sapiens*, or did we gradually acquire the stuff of modern behavior via our ancestors?

About an hour's drive away, at Wonderwerk Cave, the University of Toronto's Michael Chazan and colleagues are overseeing fresh excavations that may help answer these questions. The digs may also unearth evidence to support two theories about what ultimately made us human: The late archaeologist Glynn Isaac suggested it was a social structure built around communal life in protected base camps, while primatologist Richard Wrangham believes it was the use of fire by *Homo erectus*, as early as 1.8 million years ago.

So far, evidence of fire at Wonderwerk goes back 1.1 million years, strengthening Wrangham's claim, but Chazan is confident current excavations will push that date back further. What he is less certain of is whether *Homo erectus* was living in camps, or that the oldest use of fire at Wonderwerk will resemble the closely tended fires used by modern hunter-gather groups.

Wrangham's hypothesis, says Chazan, is that the use of fire was "like an on-off switch." Once toggled, humans from *H. erectus* to our own species developed culture and society around the fire's glow. Once our ancestors began using it, fire drove evolution: The shift to cooked meals propelled changes to tooth, gut and brain size. It's still unknown whether this hypothesis will be borne out by Chazan's work — and whether early hominin fossils will be found at Wonderwerk or Kathu to reveal just who built the tools and manned the fires.

As the dig continues, one thing is certain. "In terms of what fire means for human evolution, it's absolutely critical," says Chazan. "And this is the place to look for it."

Natural light pierces the entrance of Wonderwerk Cave (top), home to evidence that hominins used fire 1.1 million years ago and possibly even earlier; they also left cave paintings to document their world (below). A hand ax of the Acheulean style (above), found in nearby Kathu, may be a million years old. These early hominin tools are found in abundance here at the Kalahari Desert's edge.

RISING STAR

Tip of a Mystery

Back in The Cradle, little more than a mile from Sterkfontein, a mystery has emerged from the depths that could explode our understanding of our family tree, as well as what it means to be human.

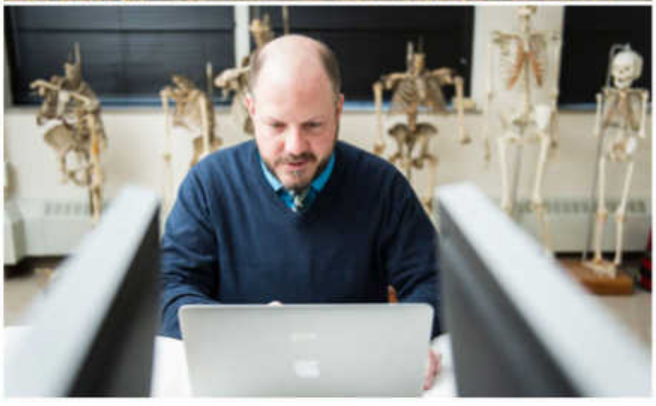
In September 2015, Berger and his team published the description of a massive trove of fossils — 1,550 fragments from at least 15 individual hominins — from the Dinaledi Chamber of the Rising Star cave system.

Not without controversy, Berger said these fossils represented yet another new species, this time from our own genus: *Homo naledi*, or star man.

Rising Star's significance is tremendous. The site contains, by far, the most hominin fossils found in a single excavation, including the only fully articulated early *Homo* hand. Like *A. sediba*, *H. naledi* has a disparate mosaic of ancient and modern anatomical features. But what caught the world's attention was where the fossils were found: deep within the cave, beyond nearly impassable shafts, alone, without other material, such as the bones of prey animals. The best explanation, the authors wrote, was that *H. naledi* was put underground by its kin in a form of "deliberate body disposal."

Although *H. naledi*'s cranium is shaped like that of *H. erectus*, its brain size is that of an earlier australopith, and tiny for its 5-foot-tall body. Its small brain challenges an assumption that large brains

See more of South Africa's hominin sites at **DiscoverMagazine.com/Cradle**



Homo sapiens **squeeze through nearly impassable areas to reach the** ***Homo naledi*** **fossils within the Dinaledi cave system (top). The South African landscape nearby, where researchers set up camp, gives no hints of the hidden wealth of material about our ancient relatives (middle). Paleoanthropologist and** ***H. naledi*** **team member John Hawks expects to study the enigmatic new member of our family tree for years (above).**

THIS PAGE, FROM TOP: ROBERT CLARK; JOHN HAWKS/UNIVERSITY OF WISCONSIN-MADISON; JEFF MILLER/UW-MADISON. OPPOSITE, FROM TOP: JOHN HAWKS/UW-MADISON; ROBERT CLARK

are required for complex behavior, such as negotiating the cramped depths of a cave, in total darkness, apparently to dispose of its dead.

"It's a non-human species of animal," says Berger, "that's doing something that we thought perhaps defined us — and by us, I mean us sitting in this room."

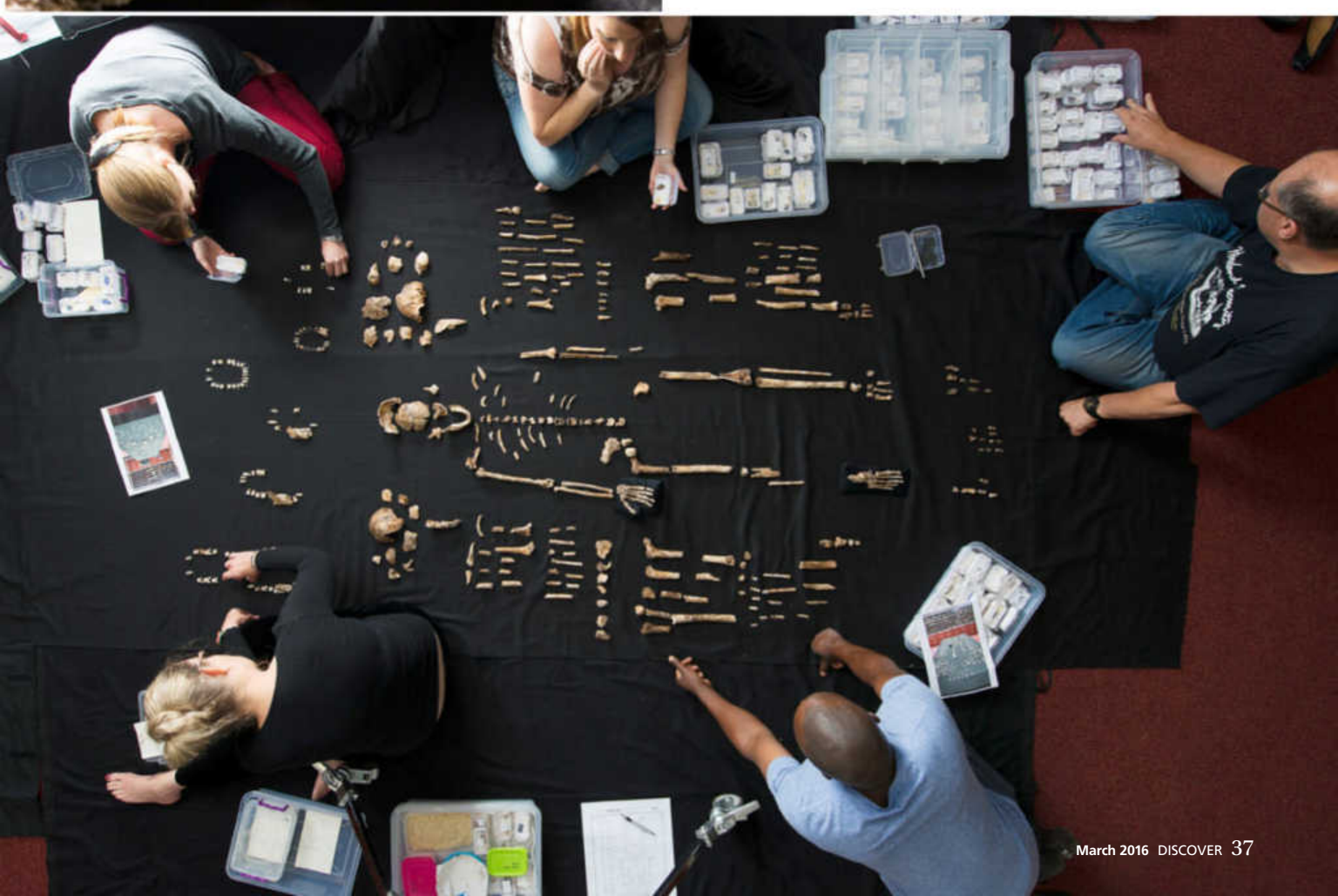
Whether or not the remains were really brought into the cave intentionally, it will be difficult to determine how old they are. The researchers hope to get a rough age range for the fossils by dating flowstones — calcite structures formed slowly by dripping water — in adjacent rock layers. And though paleoanthropologists see the Rising Star discovery as a major breakthrough, some question whether there's enough evidence to prove that the hominins found in the cave are a new species. These same critics argue that without an age for the fossils, Rising Star's ability to shed light on the course of human evolution is limited.

Such debates are the stuff of science, requiring time, and rigorous work, to resolve. But what is certain is that as we attempt to unravel the deepest of human mysteries — our origin story — South Africa will be a growing part of the discussion.

The "East Side Story," as Berger refers to paleoanthropologists' decades-long focus on East Africa as humanity's homeland, is moving south. D

Russ Juskalian *is a 2015 Alicia Patterson Foundation fellow. He is currently investigating rhino conservation.*

H. naledi **fossils from the Rising Star cave system include a well-preserved, articulated hand (left); the broad thumb suggests the hominin was a skilled climber. The find is one of more than 1,550 fragmentary fossils of** ***H. naledi****, which had an unexpected mix of features. The research team lays out some of the pieces of the latest evolutionary puzzle at the University of the Witwatersrand in Johannesburg (below).**



Taste Test

Children choose healthy foods when left to their own devices, according to a classic experiment. Do those results still hold up?

BY **BEE WILSON**

PHOTOS BY **WILLIAM ZUBACK**

"He won't eat anything but cornflakes,"

complained the mother of a boy I used to know. Breakfast, lunch, dinner — always a bowl of cornflakes and milk. Even at other people's houses, he made no concessions. To his mother, his extreme diet was a source of worry and exasperation. To the rest of us, he was a fascinating case study. Where did it come from, this bizarre cornflake fixation? It just seemed to be part of his personality, something no one could do anything about.

Whether you're a child or a parent, the question of "likes and dislikes" is one of the great mysteries. Human tastes are astonishingly diverse and can be mulishly stubborn. Even within the same family, likes can vary dramatically from person to person. Some prefer the components of a meal served separate and unsullied, with nothing touching; others can fully enjoy them only when the flavors mingle in a pot.

Because our tastes are such an intimate part of our selves, it's easy to make the leap to thinking they must be mostly genetic: something you just have to accept as your lot in life.

Parents often tell children their particular passions place them on this or that side of the family — you got your fussiness from your grandfather! — as if you were destined from birth to eat a certain way.

The question remains to what extent we can override this genetic inheritance and learn new tastes. This riddle can seem impossible to unravel, given children don't learn to eat under laboratory conditions. As we take our first bites, our parents supply us simultaneously with both nature (genes) and nurture (environment in its broadest sense, including everything from cuisine to family dynamics to religion to cutlery and table manners to the ethics of meat to views on whether it's acceptable to eat food off the floor if it was there for only five seconds). The two are so intertwined, it's hard to tell where one starts and the other stops.

In one remarkable experiment, however, a group of children did learn to eat under lab conditions. In the 1920s and '30s, Clara Davis, a pediatrician from Chicago, spent six years trying to study what children's appetites would look like if allowed to blossom without any preconceived ideas of what tasted good. Davis' results have often been taken as a clear indication that likes and dislikes are fundamentally built-in and natural, though, as we'll see, Davis herself drew a rather different conclusion.

THE EATING EXPERIMENT ORPHANAGE

In 1926 at Mount Sinai Hospital in Cleveland, Davis started the most influential experiment ever conducted to address the question of human likes and dislikes. As a doctor, Davis saw many children with eating problems — mostly refusal to eat — whose appetites didn't match their nutritional needs. She wondered what children's appetites would look like, freed from the usual pressures of parents and doctors pushing them to eat nutritious foods such as cereal and milk, regardless of whether they liked it. Conventional medical wisdom at that time was that children's particular likes should not be indulged, lest they became "faddy." But Davis wasn't so sure eating what you liked was automatically a bad thing.

She borrowed a number of infants — some orphans from

Food Choices at the Orphanage

Clara Davis, as she appeared in a 1918 photograph, spearheaded the classic food-choice study.

1. Water
2. Sweet milk
3. Sour (lactic) milk
4. Sea salt
5. Apples
6. Bananas
7. Orange juice
8. Fresh pineapple
9. Peaches
10. Tomatoes
11. Beets
12. Carrots
13. Peas
14. Turnips
15. Cauliflower
16. Cabbage
17. Spinach
18. Potatoes
19. Lettuce
20. Oatmeal
21. Wheat
22. Cornmeal
23. Barley
24. Ry-Krisp
25. Beef
26. Lamb
27. Bone marrow
28. Bone jelly
29. Chicken
30. Sweetbreads
31. Brains
32. Liver
33. Kidneys
34. Fish (haddock)

A photo from Davis' 1928 paper shows foods from the eating experiment. Babies in the study were given around 10 foods to pick from at a time, presented minced, mashed or ground up in bowls or cups they could point at.

It's unlikely any scientist will collect such detailed data again, given the dubious ethics of keeping children locked up in an experimental nursery for so long.

institutions and some the children of teenage mothers and widows — and placed them on a special self-selection diet under her medical care. The children — age 6 months to 11 months, who had not tasted solid food yet — were offered a selection of whole, natural foods and given free rein to eat only what they wished. (See the full list on the previous page.)

At each meal, the infants could choose from around 10 foods off this list, all of them mashed, ground up or finely minced. Some, such as bone marrow, beef, peas and carrots, were offered both cooked and raw. The selection was laid out in bowls while nurses sat by, waiting to see what the children chose. As Davis described it:

> *"The nurse's orders were to sit quietly by, spoon in hand, and make no motion. When, and only when, the infant reached for or pointed to a dish might she take up a spoonful and, if he opened his mouth for it, put it in. She might not comment on what he took or did not take, point to or in any way attract his attention to any food, or refuse him any for which he reached. He might eat with his fingers or in any way he could without comment or correction of his manners."*

Davis continued this experiment for six years, starting with three babies and building to 15. The results, which doctors have hotly discussed ever since, were dramatic. Without any preconceived notions about what foods were suitable for them, the babies showed enthusiasm for everything from bone marrow to turnips. They didn't realize they weren't supposed to like beets or organ meats. All of them tried all 34 foods, except for two who never attempted lettuce and one who shunned spinach.

Within a few days, Davis noticed, "they began to reach eagerly for some and to neglect others, so that definite tastes grew under our eyes." It soon became obvious to her that for the 15 children, there were 15 different patterns of taste. The children made some very odd selections, which looked like a "dietician's nightmare," she said. One day, they might gorge on liver or eat a meal of nothing but bananas, eggs and milk. A boy, Donald, showed a rare passion for oranges, cramming in nearly 2 pounds of them one day. In the process of trial and error of finding out what tasted nice, some of the children "chewed hopefully" from plates and spoons, while others grabbed handfuls of pure salt. On trying something new, Davis observed that their faces initially showed surprise, then indifference, pleasure or dislike.

However bizarre and unbalanced the children's likes and dislikes look to our eyes, they served them well. In a 1928 article writing up her findings, Davis included a before and after photo of one child, Abraham G. At 8 months, upon arriving in her care, he looks a little pale. At 20 months, after a year on the diet, he is cherubic and plump.

When they arrived at the hospital, the infants were generally in poor health. Four were seriously underweight; five had rickets. Yet within a few months, all were pink-cheeked and optimally nourished. One of the rickets sufferers was offered cod liver oil, which he took the occasional glug of, but the other four managed to get enough vitamin D and calcium to cure their rickets through diet alone. When they suffered colds, they appeared to self-medicate, eating vast amounts of carrots, beets and raw beef. Even though they had no guidance on what their bodies needed, their ratio of calories averaged at protein 17 percent, fat 35 percent and carbohydrates 48 percent — much in line with contemporary nutritional science.

DAVIS' LASTING LEGACY

Davis created an unprecedented body of information on childish appetites (though it was never fully analyzed, and after she died in 1959, all of the raw data were discarded). When Davis took a new job, the original setup in Cleveland moved to Chicago, where she established what amounted to "an eating-experiment orphanage." In all, she logged around 36,000 meals, recording changes in height and weight, blood and urine, bowel movements and bone density.

It's unlikely any scientist will collect such detailed data again, given the dubious ethics of keeping children locked up in an experimental nursery for so long. The babies stayed on the diet for at least six months and up to four and a half years, during which they were always at the hospital.

"The wisdom of the body" is an alluring theory. Eating would be such a simple business, if only we had little memos inside our bodies telling us what we needed to eat at each precise moment.

No friends visited, and those who were not orphans had little or no parental contact — their lives were subordinated to the needs of the experiment. But Davis evidently cared for the children very much, in her way. She adopted two, as a single mother: Abraham G, the plump cherub; and Donald, the passionate orange eater.

It was such an extraordinary, audacious, borderline-crazy thing: to get to the heart of where children's food passions come from. It's just a shame that her experiment proved so easy to misread. Time and again, Davis' orphanage has been cited as evidence that appetite is mostly genetic and that the foods children like or dislike are a sure guide to what their bodies need. What this interpretation fails to consider is that Davis radically restructured the children's food environment.

She was the first to point out that the real secret was her choice of the 34 foods — all unprocessed whole foods. With such foods preselected, it didn't matter which ones the children were drawn to on any given day because, assuming they took food from several bowls each meal, they couldn't help but eat a diet of an excellent standard of nutrition. Davis said her food choices were designed to mimic the conditions of "primitive peoples," though the servings were surely more plentiful. The experiment proved that when your only food choices are good ones, preferences become unimportant. The 15 patterns of taste resulted in a single healthy whole-food diet because of the setup. There was no option to like unhealthy food and dislike healthy food.

Davis herself concluded her experiment showed the food selection for young children should be left "in the hands of their elders where everyone has always known it belongs." It was obvious to her there was no "instinct" pointing blindly to the good and bad in food. The two most popular foods overall in her study were also the sweetest: milk and fruit. Had she offered a choice of sugar and white flour, staples of a 1930s diet, it's unlikely the children would've ended up in such fine fettle. Self-selection, she concluded, would have little or no value if children selected from "inferior foods."

The real test would be to offer newly weaned infants a choice between natural and processed foods. This would've been Davis' next experiment, but the Depression dashed this prospect, as her funding ran out at the crucial moment. Nonetheless, her experiment left a powerful legacy that took no account of the trick at the heart of it. Doctors, particularly in America, interpreted her experiment to mean that children's appetites are built-in and benign, without paying attention to the way Davis had changed the babies' food environment.

Influenced by Davis, the dominant view on appetite among pediatricians became "the wisdom of the body," which went along with the vogue for child-centered learning. In 2005, pediatrician Benjamin Scheindlin noted Davis' work contributed to a widespread change in attitudes in pediatric medicine from the 1930s onward. Whereas a previous generation lamented the pickiness of children's changeable tastes, now doctors positively welcomed childish vagaries of appetite.

Many child-rearing experts still think like this, operating on the assumption that children are born with special appetites for exactly the nutrients they most need and that it will all balance out, if only they are given free rein to eat what they like. As recently as 2007, a popular website about feeding children discussed Davis and concluded there was "a strong biological plausibility . . . that children will instinctively choose a balanced diet."

BEYOND THE ORPHANAGE

"The wisdom of the body" is an alluring theory. Eating would be such a simple business, if only we had little memos inside our bodies telling us what we needed to eat at each precise moment. (Your vitamin C levels are dropping — quick, eat a kiwi!) The scientific evidence — both from humans and rats — shows the theory is flawed at best. For it to be true, omnivores would need specific appetites for the essential nutrients the body needed at any given time. This is a very unlikely proposition, given the nutrients omnivores need come in so many guises, depending on the environment we happen to live in. An innate appetite for the vitamin C

in black currants would be no use if you lived where black currants don't grow.

In lab conditions, rats — our fellow omnivores — have shown a very erratic ability to self-select the diet that would do them the most nutritional good. Other trials have attempted to find out whether rats could self-select to correct certain vitamin deficiencies and concluded many of them couldn't. As for human subjects, there is, notes one specialist in the field, no data to suggest innate appetites for specific foods. It does seem possible for humans to learn specific appetites that will correct certain imbalances — particularly a salt craving when lacking in sodium — but that's a different matter.

Ninety years after Davis' experiment, the view that food likes are predominantly innate — or genetic — looks shaky. When trying to get to the bottom of where tastes come from, scientists have often turned to twins. If identical twins share more food likes than non-identical twins, the chances are that there is a genetic cause. Twin studies suggest that many aspects of eating are indeed somewhat heritable. Body weight — measured as body mass index, or BMI — is highly heritable in both boys and girls. So is dietary restraint, or the mysterious urge to resist eating the thing you want to eat.

But studies that look at likes and dislikes are much less conclusive. In one study of 214 same-sex twins, identical twins were more likely to enjoy the same protein foods, but when it came to fruit and vegetables, their likes were only marginally more similar than with the pairs of non-identical twins. Overall, the evidence for tastes being heritable is very modest, accounting for only around 20 percent — at most — of the variation in foods eaten.

Genes are only part of the explanation for what we choose to eat. As one senior doctor working with obese children put it to me, you could be cursed with all the genes that make a person susceptible to heart disease and obesity and still grow up healthy, by establishing balanced food habits. "All of it is reversible," he said. Parents and children resemble each other no more in the foods that they like than couples do, suggesting that nurture — the people you eat with — is more powerful than nature in determining our food habits.

Whatever our innate dispositions, our experience with food can override them. Maybe you share your parents' hatred of celery because you have seen them recoil from it at the dinner table. Researchers found when they gave three groups of preschool children different varieties of tofu — one group had plain tofu, one ate it with sugar and one with salt — they quickly came to prefer whichever one they had been exposed to, regardless of their genes. It turns out that, so far from being born with genetically predetermined tastes, our responses to food are remarkably open to influence, and remain so throughout our lives.

Genes do make a difference — to the foods we like, the way we taste them and even how much we enjoy eating — but they turn out to be much less significant than the environment we learn to eat in. Apart from changing the infants' food environment, there was another bigger trick to Davis' experiment, one she did not mention, perhaps because it is so obvious. She radically changed the children's social experience when eating, removing extraneous social influence. They ate without anyone caring what they ate, without any siblings fighting them for the last slice of pineapple, without any surrounding ideas about cuisine.

Davis was mistaken if she thought this was the way to discover the true nature of children's appetites. Though the nutritional outcomes were excellent, it was a not-quite-human way to eat, and one that no child in a real situation will ever replicate.

We cannot arrive at the truth about appetite by removing all social influences. Appetite is a profoundly social impulse. To a large extent, our likes and dislikes are a response to the environment we eat in. From our first toothless tastes, we pick up cues about which foods are desirable, and which are disgusting, which sadly are so often the very ones the grown-ups most want us to eat. D

BLACKOUT of the CENTURY

An unlikely trio has come up with a surprising new way to predict power failures, but will it be enough to avert the next big one?

BY **PETER FAIRLEY**

A power failure in the western United States, as depicted in this photo illustration, may be devastating — and inevitable.

PHOTO ILLUSTRATION BY ALISON MACKEY/DISCOVER, BASED ON NASA EARTH OBSERVATORY IMAGE BY ROBERT SIMMON, USING SUOMI NPP VIIRS DATA PROVIDED BY CHRIS ELVIDGE/NOAA NATIONAL GEOPHYSICAL DATA CENTER.

On a searing Thursday afternoon in September 2011, a technician reconfiguring circuits at an electrical switchyard near Yuma, Ariz., prematurely cranked open a hand-operated switch. This tiny misstep shorted out the Southwest Powerlink — a major electrical artery for the region and a key part of the entire Western grid — and sparked one of the biggest blackouts ever to strike North America.

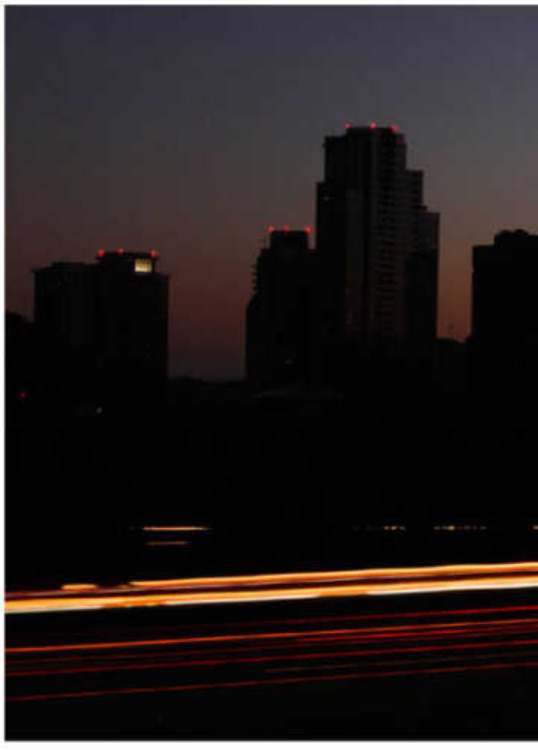
As electricity sought new paths across the network, other lines overloaded, snapping more equipment offline. Power plants, transformers and power lines across western Arizona, Southern California and Mexico's Baja California automatically shut off to protect themselves. The climax came at 3:38 p.m. when five lines supplying San Diego simultaneously shut down, sealing that region's electrical fate. Power instantly zapped out for 7 million people.

For 12 hours, a swath of the Southwest was powerless. Commerce shut down as electronic transactions and cash registers failed. Without signal lights to guide traffic, streets jammed. Food spoiled. Millions of gallons of raw sewage escaped, tainting coastal estuaries and beaches. Hospitals, 911 call centers and other first responders struggled to meet demand while relying on limited backup power.

In all, the cost just to San Diego's economy was at least $100 million. But the price tag for big blackouts can go even higher. "When we have a blackout in New York, people die, and the cost is essentially $6 billion to $10 billion per day," New York Independent System Operator CEO Stephen Whitley said at a 2015 conference. (NYISO manages the state's power grid.) With so much at stake, the industry places a high premium on reliability.

In theory, spontaneous blackouts should never happen. According to the cardinal rules of designing and operating power grids, the system should always have enough spare capacity to sustain the loss of any single element, even one as big as the Southwest Powerlink. Grid operators create computer simulations of their grids and systematically rerun the models, taking out each element in turn, and confirm that the flows are stable.

One of the country's biggest outages originated at this Arizona substation (above) on Sept. 8, 2011, leading to blackouts in San Clemente, Calif. (below), and San Diego (right).



Operating the grid in this way is the electrical equivalent of driving with a spare tire in the trunk. Yet big blackouts keep happening. They're a tough problem to crack because power grids, often described as the world's largest machines, are massively complex systems. Big blackouts are usually the result of multiple components acting up.

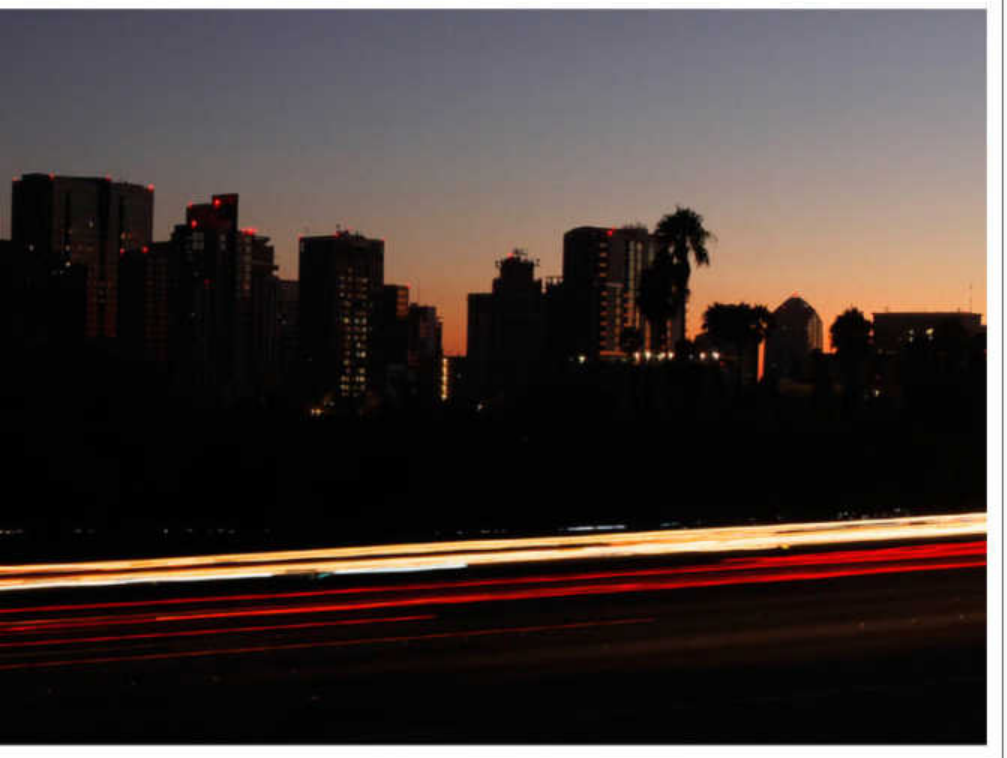
After the human error that kicked off the 2011 Southwest blackout, myriad elements of the system did not behave according to the grid operators' models. Transformers in California's Imperial Valley overloaded faster than expected, and an automated scheme shut off those five lines running south to San Diego, even though none of the lines was at imminent risk of overheating.

Forecasting events such as the Southwest blackout, in which a half-dozen or more components fail, is simply computationally impossible. "You're talking about running your model for longer than the age of the universe," says Ian Dobson, a professor of power engineering and a blackouts expert at Iowa State University. As a result, it's hard to understand the risks facing a power grid. Without the ability to simulate the largest blackouts, power grid operators can't foresee what conditions — what combinations of human and component failures — are most likely to cause them.

After 20 years of trying to get around this computational barrier, Dobson and a pair of physicists, Ben Carreras and David Newman, have found a solution. Drawing insights from the behavior of other complex systems, the trio has created a novel simulator that can mimic the largest blackouts that a power grid is likely to experience.

Experts say there is no time to lose in bringing such tools online. The trio's insights suggest that grids are vulnerable to bigger blackouts than any we've seen before. And potential triggers are multiplying as wilder weather from climate change, rising concerns over terrorism and fluctuating power from renewable energy sources heap new challenges on aging grids. "The industry needs those tools, and we need to provide them as soon as possible," says Yuri Makarov, a blackouts researcher

TOP: RANDY HOEFT/YUMA SUN; BOTTOM: MARK BOSTER/LOS ANGELES TIMES/POLARIS



at the Department of Energy's Pacific Northwest National Laboratory.

Dobson, Carreras and Newman just need to sell the power industry on heeding that warning.

THE CRITICAL POINT

The trio's hunt for the cause of big blackouts grew out of the two physicists' research on fusion energy at the U.S. Department of Energy's Oak Ridge National Laboratory in Tennessee. Newman, who as a teen developed a fascination with turbulence as a rafting guide in Colorado, arrived at Oak Ridge in 1993 to explore a different kind of turbulence: the plasma of fusing hydrogen atoms inside experimental fusion reactors. The earnest, freshly minted Ph.D. was teamed up with plasma physicist Carreras, a sharp-tongued Spaniard who was one of the lab's most distinguished scientists.

Newman and Carreras made an odd couple, but an effective one. They set out to understand the unexpected instabilities that arose when scientists sparked and tried to contain nuclear fusion, the process that fuels the stars. They produced a mathematical model showing that turbulence in fusion plasmas, contrary to prevailing wisdom, bears little resemblance to the snarling rivers of Newman's youth.

Whereas whitewater churns in response to localized conditions within the stream, the duo showed that turbulence in superheated plasma in fusion reactors has more to do with the total amount of energy in the system. After the total heat grew beyond a critical point, the probability of collapse grew exponentially.

In the parlance of systems theory, it was a classic complex system with a "self-organizing point of criticality" — a concept elaborated in the 1980s by theoretical physicist Per Bak. It describes how growing sand piles collapse in avalanches when the strain on the grains becomes too great. After a certain amount of sand is in the pile, the likelihood of collapse becomes imminent.

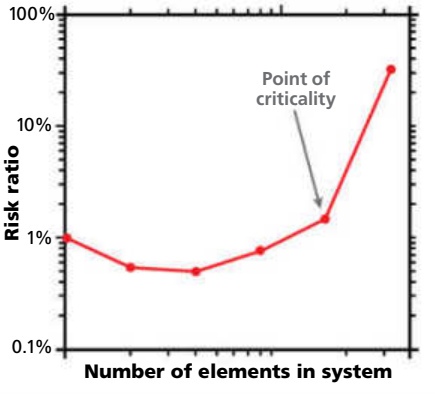
By the mid-'90s, scientists had identified similar patterns of growth and collapse in diverse natural systems, from forest fires to earthquakes. Newman and Carreras discovered that the same theory explains why plasmas have lasted no longer than a few seconds in fusion reactor tests to date. The work earned Newman a Presidential Early Career Award — the highest federal honor bestowed upon young scientists.

In 1995, Newman saw a news report on a blackout and wondered if this "point of criticality" theory might also apply to major power outages — and whether it could help prevent them. Carreras, eager for a new problem to solve, suggested they bring in a grid expert. They found one in Dobson, who had earned a reputation as an innovative power systems engineer by using advanced math to unmask unsuspected relationships between voltage drops and blackouts.

The trio first looked at the historical record of big blackouts to see if they could detect criticality's distinctive imprint. They mined a database of

Trouble Ahead

In some complex systems, from sand piles to power grids, the odds of large failure skyrocket when reaching a "point of criticality."



After a certain amount of sand is in the pile, the likelihood of collapse becomes imminent.

FROM LEFT: SEAN M. HAFFEY/ZUMA PRESS/CORBIS; B.A. CARRERAS/BACV SOLUTIONS; PHOTOVIDEOSTOCK/ISTOCK

blackouts in North America and plotted them by size. If big blackouts were just a random, unlucky confluence of many small failures, as grid planners and operators believed, a major grid collapse would occur only once in a thousand years or so, showing up as the slim tail on a bell curve. Instead, the plot bulged out to the right, showing that blackouts were striking hundreds of times more often.

For the trio, it was a strong suggestion that blackouts were, indeed, the power grid equivalent of a sand pile's avalanche. "It's as if there is a physical law there," says Carreras.

EVOLVING GRIDS

In January 2000, Carreras, Dobson and Newman reported the overabundance of big blackouts at the Hawaii International Conference on System Sciences (HICSS), one of the biggest and longest-running annual gatherings for systems scientists. They speculated that blackout risk might spike when power flows on grids exceeded some threshold, the familiar critical point in systems theory. But what was pushing grids to the point of criticality? They knew power consumption was rising, while financial pressures limited the construction of new lines. Could these

Ben Carreras (left), David Newman (middle) and Ian Dobson at the 2015 Hawaii International Conference on System Sciences, where they first presented their novel approach to studying blackouts 16 years ago.

influences combine to put extra strain on the grid's transmission lines, enough to reach a tipping point?

To test this theory, the trio realized they'd have to rethink power grid simulation. Existing simulators could not handle direct modeling of big blackouts because of the complexity of power grids. But what if they could create a simpler simulator that could be set in motion and observed as power levels increased over time, like Bak's growing sand piles?

Enlisting the help of Vicky Lynch, a gifted computational scientist at Oak Ridge, they worked out a power grid simulator that left out many of the nuances of the physics that conventional grid simulators represent, and they applied it to an artificial grid less than one-hundredth the scale of the U.S. Western grid.

Each run of the simulator represents a day in the life of a modeled grid, and each day, any of its components can fail at random. The simulator records what, if any, blackouts occur as a result. Then it evolves before the next run, strengthening affected lines to handle additional power in future runs. "It was the simplest possible power systems model, by design," says Dobson.

But it worked. The telltale pattern of large blackouts was there. On their artificial grid, just as in the archives, blackouts looked like growing sand piles or fusion reactors: complex systems. As expected, big blackouts spiked when simulated electricity flows exceeded a critical threshold. In January 2001, the trio was back at HICSS presenting their simulations.

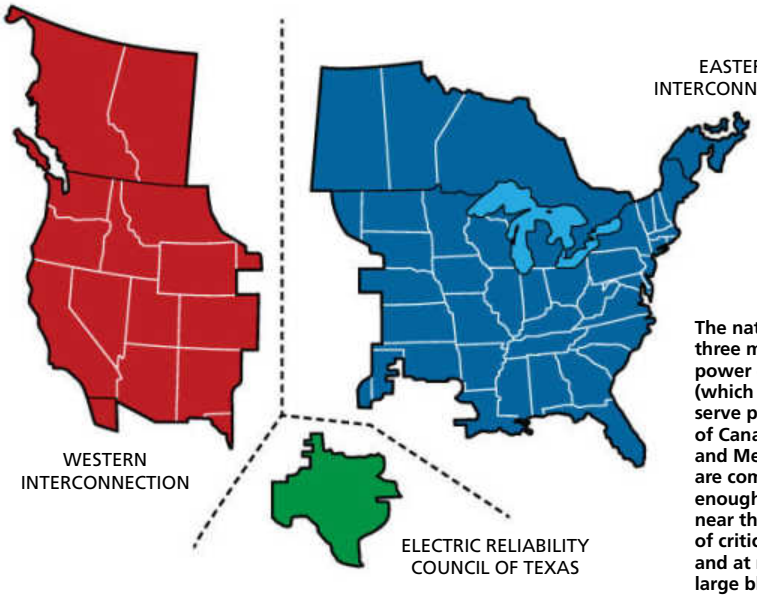
THE 100-YEAR BLACKOUT

The grid simulations cast an entirely different light on big blackouts and posed provocative new questions for grid design and operation. The most disturbing implication came from University of Vermont grid researcher Paul Hines. Following the trio's logic, he concluded that a blackout bigger than any we've seen before is probably in our future.

Using the same statistical tools that urban planners and insurance companies use to predict disasters such as earthquakes and 100-year floods based on prior patterns, Hines forecast a 100-year blackout that would knock out 186,000 megawatts of power. That is more than 23 times bigger than the Southwest blackout of 2011 and more than twice the size of North America's biggest power failure, the August 2003 Northeast blackout that left 50 million people without power.

The trio fleshed out an equally disturbing lesson on blackout prevention: The conventional practices of preventing blackouts, which involve trying to thwart even the smallest

The Major Grids



The nation's three major power grids (which also serve parts of Canada and Mexico) are complex enough to be near the "point of criticality" and at risk for large blackouts.

THIS PAGE FROM TOP: PETER FAIRLEY; JAY SMITH. OPPOSITE: ANDY KROPA/REDUX

New York lies in darkness during the 2003 Northeast blackout, which left 50 million people without power, some for up to a week. It remains North America's biggest power failure.

David Newman, now at the University of Alaska Fairbanks, argues that today's power grids may be too large, making them more susceptible to failure.

failures, may actually increase the likelihood of big ones. After tweaking the simulator settings to reduce the possibility of random line failures, the artificial grids experienced more big blackouts. Protecting the grid against small blackouts enables it to run at higher and higher power levels, ultimately setting up the grid for a major collapse.

That may seem counterintuitive, but it's in line with systems research that shows merely preventing failure can increase a system's probability of collapse. Consider forest fires: Research (and history) shows that suppressing small forest fires allows kindling to build up, setting the stage for large, truly devastating conflagrations. The trio's simulations suggest that power grids are susceptible to the same paradox.

AN INCONVENIENT IDEA

The Northeast blackout of 2003 struck at a prime moment for the trio, thrusting their theory into the media spotlight. Major newspapers and news broadcasts turned to them for help in explaining why the grid might have spontaneously collapsed. An article in the journal *Nature* captured their message succinctly: "Power grids are inherently prone to big blackouts. … Trying to make them more robust can make the problem worse."

The idea that preventing failures might unwittingly hasten big blackouts proved wildly unpopular with power companies and engineers, who struggled

Protecting the grid against small blackouts enables it to run at higher and higher power levels, ultimately setting up the grid for a major collapse.

to reassure a nervous public amid a crisis of confidence in the grid. Carreras believes the controversy put the trio's research in jeopardy; he says in fall of 2003 the director of Oak Ridge National Laboratory told him that officials in Washington were fuming over the trio's message. Carreras suspects that's why research funding from the U.S. Department of Energy dried up soon afterward. "We got cut off," he says.

They found new grants, but it was a struggle. Electrical engineers reviewing grid research proposals questioned the trio's stripped-down, low-resolution power model and took a dim view of their interdisciplinary efforts. One common refrain in grant reviews, recalls Newman, was, "What could a physicist, especially one at a podunk school, know about the power grid?"

EXTREME EVENTS

What ultimately brought the three in from the cold, a few years later, was an accelerating energy revolution in California. In 2002, the state mandated that utilities use increasing amounts of electricity from renewable sources such as wind and solar. Utility executives and state energy experts feared that these cleaner but less predictable energy sources would heighten the risk of blackouts, and to keep the power flowing, they were willing to test out-of-the-box ideas, including the trio's.

Merwin Brown — whose grid research and development program at the California Institute for Energy and Environment financed the trio's work from 2009 to 2011 — describes it as the research equivalent of a Hail Mary pass. "It kept being said that you really can't analyze these cascading outages because it's just such a huge calculation," says Brown. "My team felt that the research program should have a few long-term, high-risk, big-payoff efforts. We said, 'Let's test that hypothesis.'"

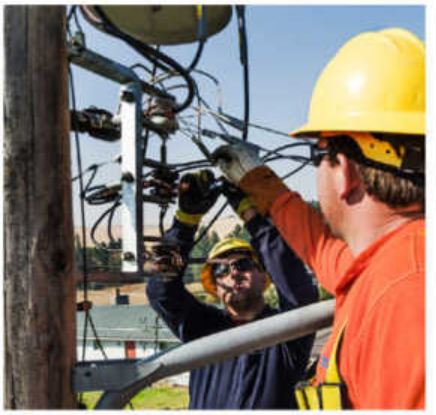
In 2006, Brown enlisted Dobson to help craft the project. The resulting $1.16 million Extreme Events initiative would test the trio's approach against the most advanced power grid simulator then available, operated by scientists at the Pacific Northwest National Laboratory (PNNL), to predict where and how often big blackouts struck.

For the first time, they had the chance to apply their simulator to a real power grid: the mighty Western Interconnection, one of the nation's three main grids, which stretches from Mexico to British Columbia and east to the Rockies. Blackouts striking California could start anywhere on the Western Interconnection and propagate across it without any political obstacles.

Brown hoped the trio and the PNNL team would work well together, but the honeymoon was short-lived. Some members of the PNNL team arrived with the same critical view that the trio faced from grant reviewers, arguing that the trio's approach could not be trusted, recalls Brown. Exchanges at the project's 2009 launch got so heated that some worried it might come to blows. Newman remembers it as a new low: "I have crazy colleagues in other areas, but I've never seen anything quite like that before."

Nevertheless, the project moved

ERIC ENGMAN/FAIRBANKS DAILY NEWS-MINER



Smart grid technologies — such as this transformer in Pullman, Wash. (above), and the Salem Smart Power Center in Oregon (right) — are no guarantee against blackouts.

FROM LEFT: AVISTA UTILITIES; PORTLAND GENERAL ELECTRIC, BOTH VIA PACIFIC NORTHWEST NATIONAL LABORATORY

forward as two separate efforts, and the trio's results, reported in March 2011, vindicated their approach. The pattern of blackouts that their simulator produced closely matched the Western grid's record of outages. In contrast, their counterpart's powerful but non-evolving simulator underpredicted big blackouts by about a factor of 10, according to calculations by Dobson and one of his students. (The PNNL team did not present its own comparative analysis of blackout frequency.)

The simulations also validated the link between power levels and risk: The probability of the biggest blackouts rose sharply when simulated power flows exceeded a critical point of roughly 50 percent of the grid's capacity limits.

More real-world validation came later that year, when the Southwest blackout struck the Western grid. In the Extreme Events final report, the trio had predicted vulnerable regions within the Western Interconnection — eight areas where large blackouts repeatedly struck their simulations. One of the eight vulnerable grid segments they identified was the quintet of lines north of San Diego whose shutdown would seal the region's fate. "It was pretty amazing," says Newman. "The actual blackout was in September. Our prediction had been in February."

SMART VS. SAFE

Validation in California helped the trio and their approach to blackouts earn the respect of the power engineering community. Their ideas have inspired researchers to use simulations to seek out the telltale overabundance of big blackouts on power grids from Scandinavia to New Zealand to China.

But changing grid operations based on the trio's basic takeaways — that big blackouts are predictable and that running power grids cooler would exponentially reduce their incidence — has only just begun.

Most power system analysis continues to use simulators that cannot predict the biggest blackouts. But power system operators do talk more openly these days about the link between power levels and risk. Whitley, the New York Independent System Operator CEO, told attendees at the 2015 HICSS meeting about a new power-trimming procedure that New York's system operators have developed to reduce risks when power consumption is running especially high.

Under the so-called "thunderstorm alert," extra power-generation facilities are turned on to reduce the power flowing long distances on the state's transmission lines. Whitley said the extra costs were justified, given the far higher costs that a blackout would impose: "If you have to run a few gas turbines for a couple of hours, who cares!" he told the assembled system scientists.

The next step for the trio is to refine tools to advise grid operators like Whitley on when and how to act to reduce blackout risk. And with power grids in the process of a redesign, the time is now, says Milorad Papic, a senior grid planner who leads an engineering society initiative on blackout analysis.

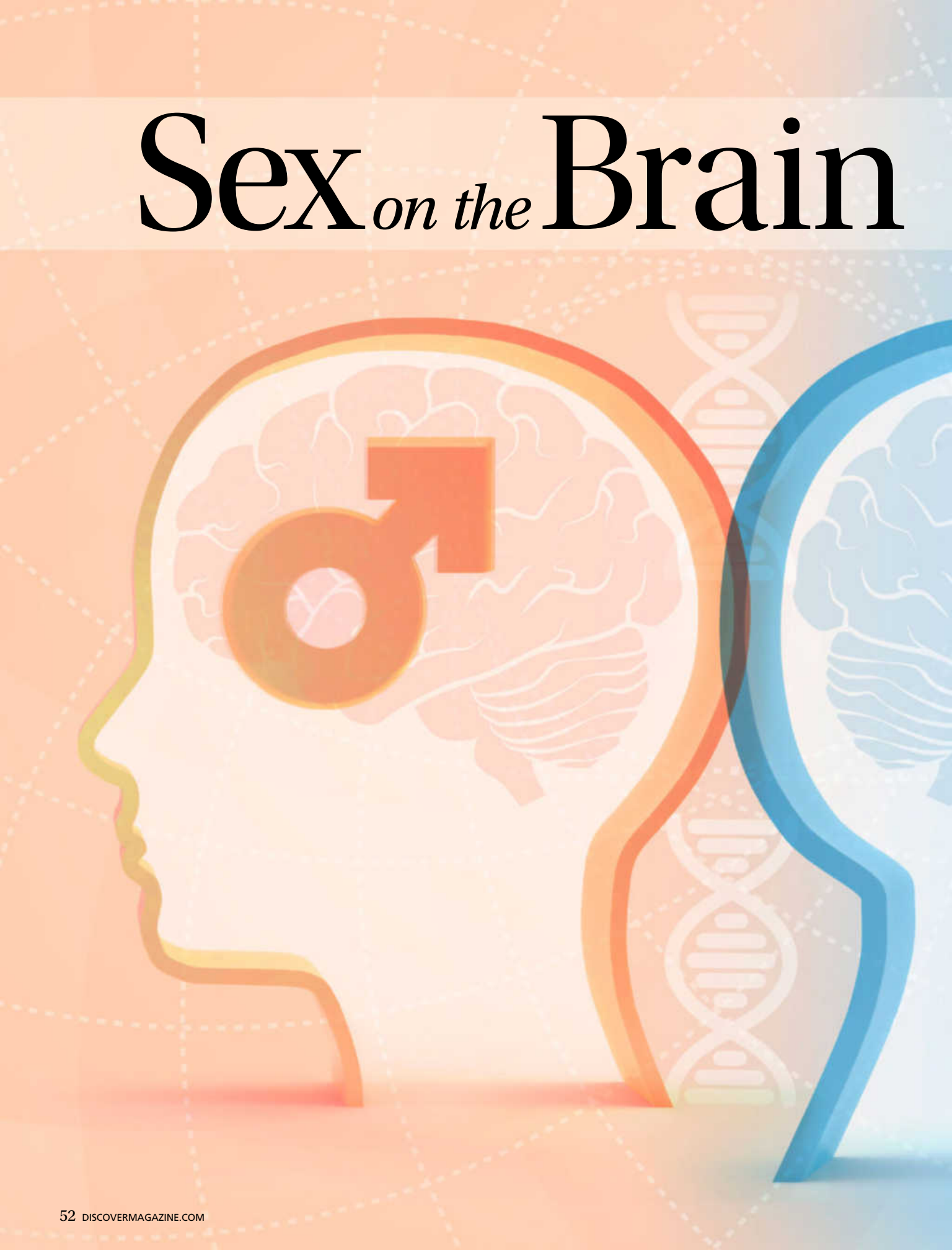
Power systems are adopting so-called smart grid technologies, such as advanced power sensors and automated switches, that could have unintended impacts on reliability, Papic notes. For example, advanced sensors are providing unprecedented real-time information on power flows that grid operators are using to monitor system stability. Whitley's team is using stability warnings from those sensors to guide the use of their thunderstorm alert. But such real-time intelligence could also entice grid operators to allow more power to flow over existing power lines.

"You're getting closer to limits, and overloads can propagate more quickly and generate more problems," Papic says. Without careful study, a smarter grid could actually become a less safe grid.

Perhaps it is inevitable — based on the trio's own research — that their insights will get short shrift until another catastrophic blackout. If they are right, we shouldn't have to wait too long: The next big one is always just around the corner. D

Peter Fairley *is a freelance science journalist who has tracked the energy story and its environmental implications for more than two decades.*

Sex *on the* Brain



When it comes to disease, mental illness and the effects of generations of trauma, men and women face different risks. Neuroscientists think it's all in the wiring. BY **LINDA MARSA**

ALISON MACKEY/DISCOVER; PROFILES: DIGITAL STORM/SHUTTERSTOCK; BRAINS AND BACKGROUND: PUWADOL JATURAWUTTHICHAI/SHUTTERSTOCK

Helen Epstein felt deeply isolated and alone. Haunted by her parents' harrowing experiences in Nazi concentration camps in World War II, she was troubled as a child by images of piles of skeletons and barbed wire, and, in her words, "a floating sense of danger and incipient harm." But her Czech-born parents' defense against the horrific memories was to detach. "Their survival strategy in the war was denial and dissociation, and that carried into their behavior afterward," recalls Epstein, who was born shortly after the war and grew up in Manhattan. "They believed in action over reflection. Introspection was not encouraged, but a full schedule of activities was."

It was only when she was a student at Israel's Hebrew University in the late 1960s that she realized she was part of a community that shared a cultural and historical legacy that included both pain and fear. "I met dozens of kids of survivors," she says, "one after the other who shared certain characteristics: preoccupation with a family past and Israel, and who spoke several middle European languages — just like me."

Epstein's 1979 book about her observations, *Children of the Holocaust*, gave voice to that sense of alienation and free-floating anxiety. In the years since, mental health professionals have largely attributed the second generation's moodiness, hypervigilance and depression to learned behavior. It is only now, more than three decades later, that science has the tools to see that this legacy of trauma becomes etched in our DNA — a process known as epigenetics, in which environmental factors trigger genetic changes that may be passed on, just as surely as blue eyes and crooked smiles.

Neuroscientist Rachel Yehuda of the Mount Sinai School of Medicine in New York had been keenly aware of the Holocaust since her childhood in a close-knit Jewish neighborhood in Cleveland. While her own parents were Israeli, she recognized in hindsight that the troubles of her friends' European-born parents went far deeper than the normal dislocations immigrants feel. The descendants showed a greater sense of insecurity and instability, and focused on the potential for impending danger even when no danger was present. "Even in good times, some offspring seemed like they were waiting for the other shoe to drop," she says.

Yehuda's later studies revealed an intriguing distinction. These children not only were affected based on whether or not their parents had symptoms of post traumatic stress disorder (PTSD). She and colleagues also learned that offspring could be affected differently by parental Holocaust trauma based

on whether it was the mother or father who was exposed. These differences were reflected in crucial changes in key brain circuits.

Her research is part of growing evidence that has yielded an entirely new understanding of molecular differences reflected in the brain between men and women, and how outside forces can permanently imprint neurological circuitry in sex-based ways. "There's a complex interplay between hormones, experience and epigenetic changes in response to life events," says neuroscientist Cheryl Sisk, who studies sex differences in the brain at Michigan State University in East Lansing.

Uncovering these differences in the hard wiring of the brain, researchers believe, can offer a better understanding of the biochemical origins of many physical diseases and psychological conditions that have few treatments. To be sure, there was a significant male bias in laboratory experiments on animals — neuroscience research skewed heavily toward the use of males, and five times more studies were conducted solely with male animals than with females or a mixture of the sexes. Scientists justified this because they believed there were no sex differences in brain function aside from reproduction.

Helen Epstein rides the shoulders of her mother, Frances, a concentration camp survivor, in 1948. Helen has written about the anxiety and alienation felt by many children of Holocaust survivors.

But recent research has proved otherwise: There is a vast divergence in brain function across the gender divide. These newer studies are beginning to uncover the reasons why men are much more susceptible to neurodegenerative diseases like Parkinson's and ALS; why autism, dyslexia, stuttering and early onset schizophrenia are three to four times more prevalent in boys; and why attention deficit hyperactivity disorder is diagnosed 10 times more often in boys. In contrast, women are diagnosed twice as frequently with depression, anxiety and panic disorders.

Drilling down to the source of these gender inequities could ultimately lead to better therapies. "While gender differences in cognitive function are small, the differences in vulnerability for diseases are spectacular," says Geert J. de Vries, a neuroscientist at Georgia State University in Atlanta. "Nature has found a way of protecting one sex better than the other against certain diseases. This research might detect protective factors and give us insights in how to better treat these diseases."

REMODELING THE CIRCUITRY

From the moment a fetus is bathed in steroidal hormones in the womb, the brain begins to take shape as male or female. "The gonads of the developing fetus are the epicenters of sex determination," notes Margaret McCarthy, a neuroscientist at the University of Maryland School of Medicine. The SRY (sex-determining region Y) gene on the male's Y chromosome orchestrates the formation of the testes, while the gonadal precursor will differentiate into an ovary by default (in the absence of the steroids produced by the testes). Other sexual characteristics depend on hormones secreted by the testes or ovaries later in embryonic development.

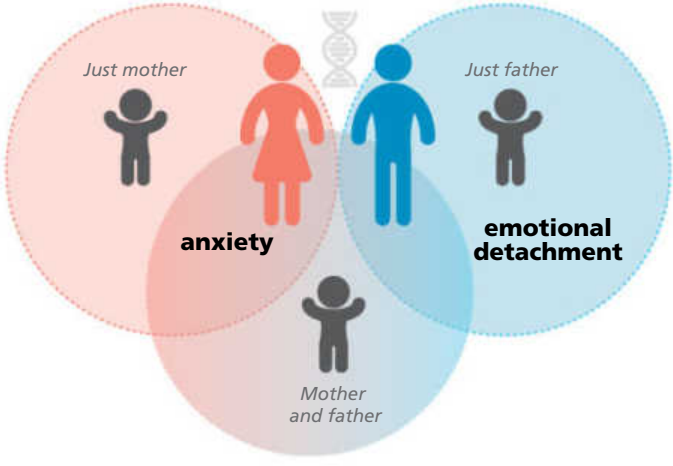
Yet the differentiation doesn't end with gestation. Scientists now know that specific brain circuits underlying sexual differentiation can be remodeled through life. Hormones drive many of these sex differences, while major life events — such as puberty, pregnancy, parenthood or even traumas — also help shape male and female brain circuitry.

Studies like Yehuda's provide a window into how this happens. Her initial research revealed that the children of Holocaust survivors were three times as likely to be diagnosed with PTSD, anxiety and depression, and engaged in more substance abuse than their peers. "Straight genetics did not explain the high prevalence of PTSD in this community," says Yehuda. "Epigenetics provided a construct to conceptualize this — that experiences stay with us, particularly the traumatic ones."

Her more recent studies revealed marked differences in the way men and women coped with the horrors of the Holocaust. In 2014, her team compared 80 adults who had at least one parent who was in the camps with 15 demographically matched controls whose families did not face the same ordeals. Participants submitted blood and urine tests and were given a battery of psychological tests to evaluate their mental health and gauge whether the parents suffered from PTSD. The results showed that the children had a different stress hormone profile than their peers: They had lower levels of cortisol, the "fight or flight" hormone that helps regulate our response to extreme stress, and greater activity of an enzyme that breaks down cortisol — two differences that might make them more prone to anxiety disorders and PTSD.

What's more, there was an increased sensitivity to cortisol if the mother, or mother and father, had PTSD. If only the father had PTSD, however, that sensitivity decreased. This

Epigenetic Inheritance in Children of Holocaust Survivors With PTSD



TOP: COURTESY OF HELEN EPSTEIN. BOTTOM: VENN DIAGRAM BY ALISON MACKEY/DISCOVER, ILLUSTRATIONS BY PUWADOL JATURAWUTTHICHAI/SHUTTERSTOCK

was reflected in subtle DNA changes in an epigenetic gene that governs the stress response: Children whose fathers were survivors had greater genetic alterations in the GR-1 promoter, a tiny spigot that normally dampens genes that shut down the stress response. In other words, a more active GR-1 promoter caused a silencing of the gene, resulting in less cortisol. Having two stressed-out parents had the opposite effect, with the spigot leading to the release of more cortisol, making the children more fearful and anxious. This made sense, says Yehuda, "because volunteers generally described their fathers as being numb and detached, though prone to explosive outbursts, while mothers were riddled with anxieties."

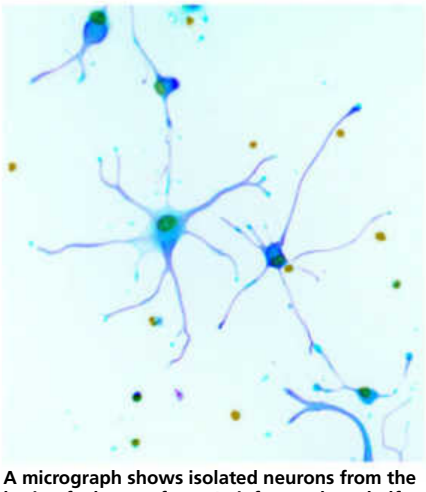
MEEK ROOSTERS

The study of gender differences in the brain and the resulting differences in behavior dates back to the mid-1800s, with the classic experiment of German physician Arnold Berthold, who showed that testicular secretions were essential for the normal expression of male actions. When he castrated a group of juvenile roosters, the fowl became puny and meek: They lost interest in the hens, they failed to sprout abundant plumage and were smaller than normal males. They didn't crow or strut like their intact brethren.

But the truly modern era of behavioral endocrinology began in the late 1940s, when scientists such as endocrinologist Alfred Jost began studying how the release of steroidal hormones like estrogen and testosterone in the womb and during infancy created permanent sex differences. In the absence of testosterone, the embryo becomes female, and when male rabbit fetuses were deprived of testosterone — like Berthold's castrated roosters — they became feminized.

Throughout our lives, these studies found, sex-specific hormones secreted by the ovaries or testes were responsible for instigating major life changes, such as the onset of puberty, having babies or fortifying parental bonds.

By the 1980s, the use of new imaging technologies like positron emission tomography (PET) provided unprecedented glimpses of a living human brain. More recently, techniques like functional magnetic resonance imaging (fMRI) have changed how we can study the brain and behavior. With fMRI, scientists get an even clearer picture of the differences because they can see which brain regions are activated while a person is thinking and processing information. "We're on the threshold of a new awareness," says Arthur Arnold, a neuroendocrinologist at UCLA who is a pioneer in the study of sex differences in the brain.



A micrograph shows isolated neurons from the brain of a human fetus. In infancy, about half the neurons will die during a pruning period.

As mammals gestate, testosterone and related hormones trigger cell death in some brain regions and spur cell development and more robust nerve connections between synapses in other regions.

DIVERGING DEVELOPMENTAL MILESTONES

Hormones regulate a lifelong reshaping of our neuronal pathways, programming a turnover and pruning of brain cells — a process that begins in the womb and continues to affect our intellectual, emotional and social development in adulthood. Studies in animals show that during a brief prenatal developmental window, testosterone and related hormones cause structural changes in the male's brain so that it differs from that of a female's. Researchers now think that in female animals, the presence of estrogen promotes female development at specific life stages, and having a second X chromosome makes female brains different from those of males.

Brain development involves an overproduction of neurons, followed by a period of trimming in which about half the neurons die during infancy. Studies in mice conducted by neuroscientist Nancy Forger of Georgia State University show that hormones act like chemical scalpels, sculpting the male brain differently from the female brain. As mammals gestate, testosterone and related hormones trigger cell death in some brain regions and spur cell development and more robust nerve connections between synapses in other regions, causing prominent sex differences in the brain and spinal cord. Forger's research, for example, has shown that males have more cells in the bed nucleus of the stria terminalis, which regulates anxiety and response to stress, and in the spinal nucleus of the bulbocavernosus, which is made up of motor neurons in the spine that control muscles attached to the penis. Females, in contrast, have more cells in the anteroventral periventricular nucleus, which is a cluster of cells that help regulate the hormones that orchestrate ovulation.

"Men and women are more the same than different in the brain, but little differences can go a long way," says Forger, who is also looking at the effects of epigenetic changes that cause differences in the brain that can last a lifetime.

Subtle changes in fetal steroid hormones may even predispose children to autism, according to a 2014 study by European researchers. They compared the concentrations of testosterone, cortisol and other hormones in the stored amniotic fluid samples of 128 Danish boys who have autism with 217 boys who do not. Tests revealed that during their fetal development, boys with autism were exposed to even higher levels of sex steroid hormones than the control group of boys. It's a significant difference, and even a small rise in testosterone and other hormones may heighten risks for autism. In the womb, boys produce twice as much testosterone

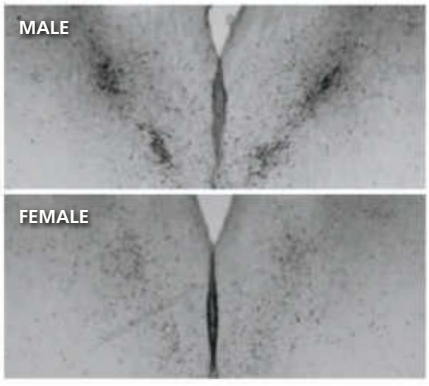
RICCARDO CASSIANI-INGONI/SCIENCE SOURCE

as girls, providing possible clues as to why autism strikes males in such disproportionate numbers.

THE IMPRINT OF EXPERIENCE

Sex differences become even more marked during puberty, when the brain undergoes another period of explosive growth. It kicks off when the hypothalamus — a tiny but powerful structure at the base of the brain — unleashes gonadotrophin-releasing hormone. This chemical signal sets off the chain reaction of physical changes that ultimately transform children into sexually mature adults. The biochemical onslaught of estrogen and testosterone sparks the development of the reproductive system and influences neurotransmitters like serotonin that regulate mood, which may help explain why teenagers can be reckless and excitable.

"We know puberty and adolescence is a major transition," says Sisk, the Michigan State neuroscientist. "Kids go wacky for a long time due to their raging hormones and other factors. Now we're trying to put all these pieces of the puzzle together to try and figure out what is going on."



Images from a mouse study show the male brain has many more cells in the bed nucleus of the stria terminalis, an area that regulates anxiety and response to stress.

Research into how pubertal hormones influence the developing adolescent brain and how they shape adult social behaviors has direct implications for human mental health. That's because a number of gender-based pathologies, such as eating disorders, depression, bipolar disorder and schizophrenia, emerge during adolescence and contribute to teen suicide. This flux in hormones can also provide insights into the biological changes that prepare us to become a sexually mature adult, as well as the complex interplay between genetically programmed changes and those that are shaped by experience and the environment.

A recent Michigan State experiment shed light on which parts of the male brain sprout new neurons during puberty. In the 2013 study, researchers injected adolescent male hamsters with a special chemical marker to detect the growth of new cells. When the hamsters matured into adults, they were allowed to mingle and even mate with the females. Immediately after these interactions, scientists examined the brains and discovered the new cells that formed during puberty had been integrated into the amygdala, an almond-shaped region deep inside the brain that is thought to play a role in such social behaviors as mating. The new research suggests this nerve growth is important for adult reproduction because it may have created neural pathways that enabled the males to interact with females.

"We know that experience is at least as powerful a regulator and shaper of brain structure and function as hormones, and boys and girls have very different experiences," says Sisk, who was involved in the study. "The brain metamorphosis of puberty … is not just about the fine tuning of synapses or making more of a particular neurotransmitter. It's really a complete makeover that includes the addition of brand-new cells in places we never considered before to give us the tools we need to navigate our way through the human social fabric as adults."

The turmoil of the teenage years also can drive hormonal changes that permanently alter neural pathways for emotional regulation. How each sex handles these stresses provides clues into the biological roots of gender differences in incidences of mental illnesses, and illuminates why women have higher levels of anxiety and depression. In 1989, University of Wisconsin researchers launched a longitudinal study, called the Wisconsin Study of Families and Work, which collected medical and demographic data on several hundred children from birth to early adulthood. In a 2002 study that followed 174 of these kids, researchers reported that 4-year-olds living in stressful environments — their mothers were depressed, their parents fought, or there were financial difficulties — had high levels of the stress hormone cortisol in their saliva. When the children were observed two years later, those with more cortisol exhibited greater behavioral problems, such as aggression and impulsivity.

The researchers checked back in with the study subjects when they turned 18 to find out how the increased cortisol affected their brain function. Researchers scanned the brain connections of 57 participants — 28 females and 29 males — using fMRI. Brains of teenage girls exposed to high levels of family stress when they were toddlers showed reduced connections between the amygdala, which is also known for processing fear and emotions, and the ventromedial prefrontal cortex, an outer region responsible for emotional regulation. This correlated with anxiety in adolescence: Girls with higher scores on anxiety tests have weaker synchrony between these two regions. Yet the young men in the study didn't exhibit any of these neural patterns, suggesting that this may be a developmental pathway that makes females more prone to becoming anxious. "Males are better at avoiding depression," says Georgia State's de Vries, "and experiments like these may illuminate their protective factors."

Autism, dyslexia, stuttering and early onset schizophrenia are **three to four times more prevalent** *in boys*

Women are diagnosed **twice as frequently** *with depression, anxiety and panic disorders*

Attention deficit hyperactivity disorder is diagnosed **10 times more often** *in boys*

COURTESY OF NANCY FORGER

PARENTING REWIRES THE BRAIN

As we move into adulthood, parenting also generates brain changes along sex-related lines. Expectant mothers spend nine months marinating in a flood of hormones that alter their brain circuitry. Once they give birth, hormones are released to stimulate lactation and to cement an emotional bond with their newborns. Preparing for parenting rewires fathers' brains as well, but in a different way. For mothers, that hormone surge is part of an exquisitely choreographed internal program that nurtures developing fetuses throughout pregnancy. For fathers, the social interaction with their offspring spawns binding neural ties.

One study found that when paternal mice snuggled with their newborn pups in the nest, it prompted the formation of new brain cells that created a lasting connection with their offspring. Samuel Weiss, director of the Hotchkiss Brain Institute at the University of Calgary, and his colleagues reported that nerve cells sprouted in the olfactory bulb, the seat of the sense of smell, and in the hippocampus, the brain's memory bank. These particular brain cells are also regulated by prolactin, a hormone that orchestrates the milk production in the breasts of new mothers. In the fathers, a surge of prolactin helped the neurons form a permanent circuit in the brain, which integrated a pup's scent into the father's long-term memory. As a consequence, even when the fathers were separated from their babies for a few weeks — normally enough time to forget cage mates — they easily recognized their pups when they were reunited. But new neurons formed only if the father had physical contact in the nest with the pups.

One study found that when paternal mice snuggled with their newborn pups in the nest, it prompted the formation of new brain cells that created a lasting connection with their offspring.

"The nuzzling stimulates the production of the hormone prolactin," says Weiss. "If you block prolactin, it stops brain cell production, and memories aren't formed because no nerve cells are produced. But this has long-term implications for mental health because these social interactions yield the release of hormones that change the brain, which, in turn, forms social memories. And these memories reinforce positive social interactions, creating positive feedback loops."

On the epigenetic side of the equation, research into different parenting behaviors indicates that positive experiences may become embedded in our DNA — and in a way that also breaks down along gender lines. While Yehuda's research on the children of Holocaust survivors suggests we can't escape the legacy of trauma experienced by our parents, the opposite may be true, too: Healthy parenting can have a salutary effect on not only their offspring but also future generations.

Weiss' group looked at how different parenting models affected new nerve growth in the brain, and the behavioral impact of the neurological changes. They used 8-week-old mice and placed them into three distinct environments. In the first group, mothers raised their litters alone until their pups were weaned; in the second, the impregnated females were put in cages with virgin females who helped them rear the young mice; and the third group consisted of pups reared by both parents. When the young animals were successfully weaned, researchers gave them a series of tests to gauge their fear response, along with their cognitive, memory and social skills. The mice were also injected with a dye that could illuminate the footprints of new nerve cell growth in the brain.

Perhaps not surprisingly, two parents were better than just one, although it didn't matter whether it was a combination of mom and dad or the two females. The extra attention the offspring received in the enriched environments — nursing, licking and grooming — translated to denser nerve growth in the dentate gyrus, which is in the hippocampus, the brain's memory warehouse believed responsible for learning and storing short-term memories.

But while male pups raised by two parents produced more gray matter in the memory-processing regions, dual-parented females sprouted twice the number of nerve cells in the corpus callosum, a thick bundle of nerve fibers that enhances communications between both sides of the brain and facilitates spatial coordination and sociability.

In fact, female mice raised by two parents were more proficient at negotiating a ladder with uneven rungs than females with just one parent — and all females were far more adept at this task than the males, even those reared by two parents. These effects endured not only throughout the animals' lives but were carried on to the next generation and along the same gender lines: The offspring of dual-parented pups turned in superior performances on tests of cognitive ability and social skills than mice raised by single parents.

"We already know that in humans, positive early experiences lead to stronger adults that have less problems coping and managing life's challenges, but the generational results are mind-numbing — who would imagine that if you have a positive early experience that your offspring would benefit?" says Weiss. "We're not that far away from the point where we will be able to explore similar things in humans." D

Visit **DiscoverMagazine.com/Grandmas-experiences** for more on how epigenetics can play out through generations.

Linda Marsa *is a contributing editor for* Discover *and the author of* Fevered: How a Hotter Planet Will Hurt Our Health and How We Can Save Ourselves.

ORKEMDEMIR/ISTOCK

CELESTRON

COMMAND THE COSMOS

SKYPORTAL APP **UPDATE** + STARSENSE

TWO OF CELESTRON'S CUTTING-EDGE TECHNOLOGIES JOIN FORCES

Groundbreaking enhancements now enable automatic telescope alignment and complete wireless control from your smart device. Astronomical observing has **NEVER** been easier!

HERE'S WHAT YOU NEED:

CELESTRON COMPUTERIZED TELESCOPE WITH WIFI

NexStar Evolution features built in WiFi, or upgrade most Celestron computerized telescopes using the SkyPortal WiFi module.* This allows full wireless control of your telescope from your smartdevice.

STARSENSE AUTOALIGN*

Attaches to your telescope and automatically aligns in 3 minutes or less; no need to identify or locate alignment stars.

SMARTPHONE DEVICE OR TABLET

Download or update the **FREE** Celestron SkyPortal app for Android or iOS.

APP + WIFI + STARSENSE = AUTOMATIC ALIGNMENT - WIRELESSLY!

Google play Available on the App Store

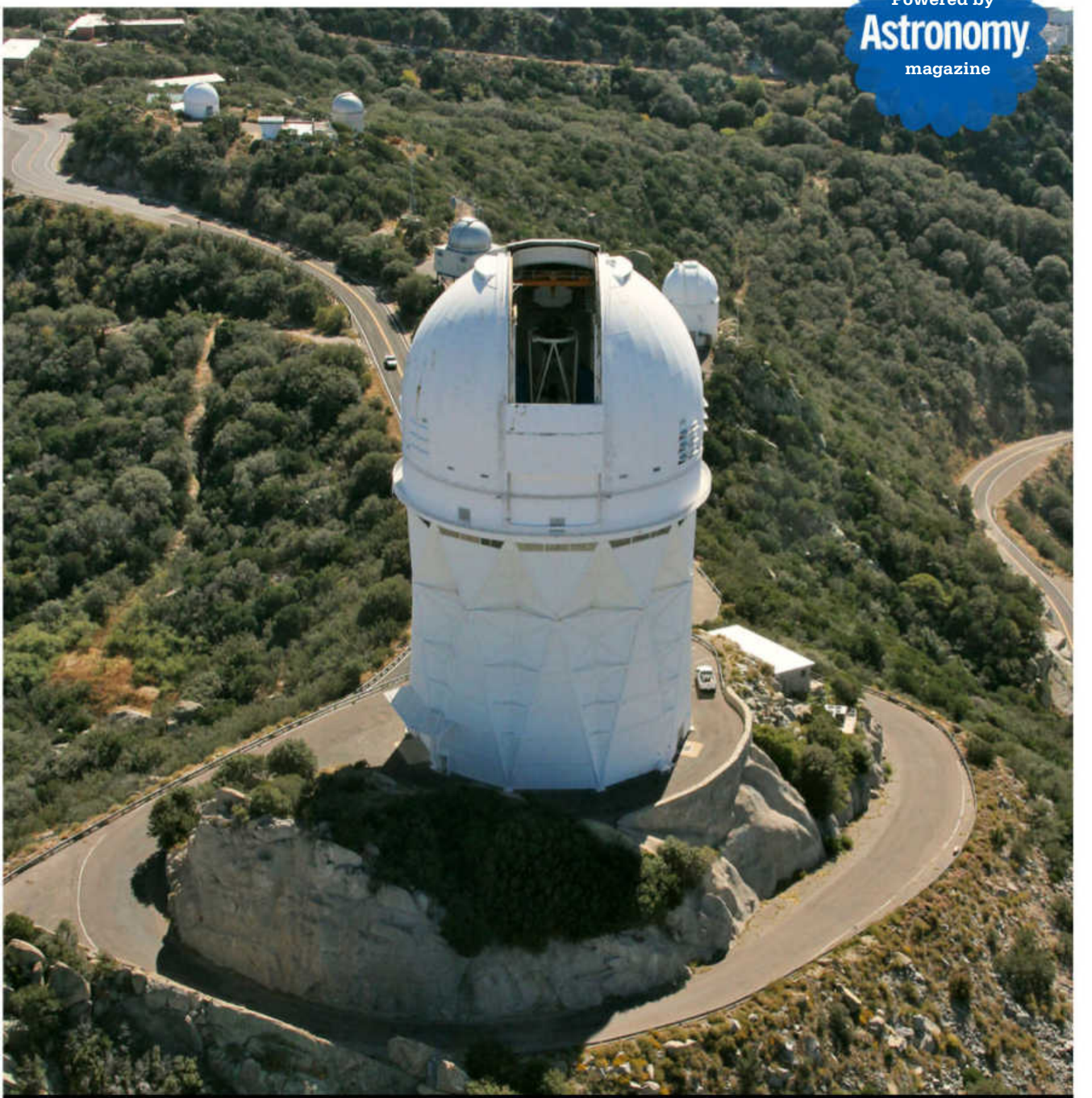
* ACCESSORY SOLD SEPARATELY

SPECIAL BONUS SECTION

OUT THERE

A Look at the Universe and All Its Wonders

Powered by Astronomy magazine

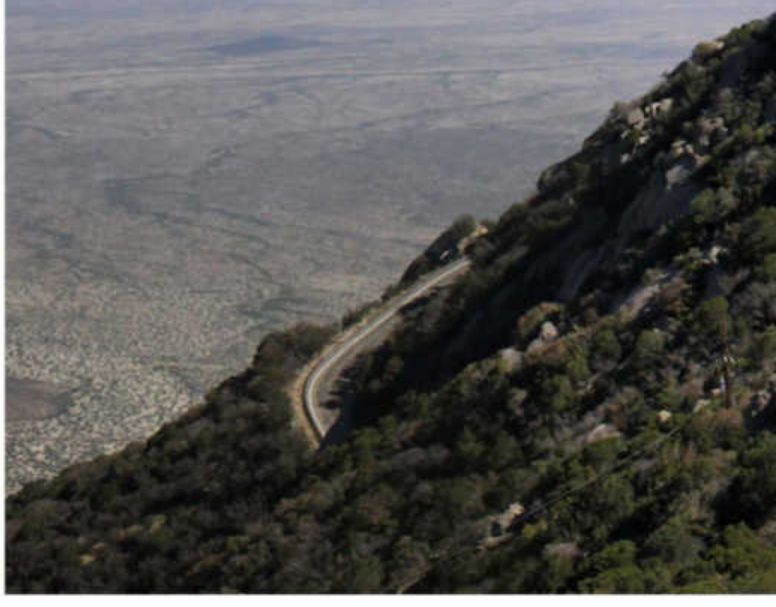


AN OBSERVATORY'S NEW LIFE
After more than four decades of service, the aging Mayall Telescope atop Arizona's Kitt Peak will soon see farther than ever into space, thanks to a novel camera that will pinpoint the location of 25 million galaxies up to 10 billion light-years away. Turn the page to read more about how new technology will help old observatories keep their eyes on the skies for years to come. —ERNIE MASTROIANNI; PHOTO BY NOAO

Kitt Peak Observatory's Second Chance at Life

The next generation of mega telescopes promises to democratize astronomy, but aging national observatories must redefine their relevance to survive the revolution.

BY **ERIC BETZ**



NOAO/AURA/NSF

Hillary Mathis helped construct one of the most unusual astronomical instruments ever conceived. She was still an undergraduate when she worked on a set of nine cartridges designed to hold circular metal plates. The plates are pockmarked with hundreds of holes, like thinly sliced aluminum tree trunks beset by demonic termites. Each hole is drilled for a specific galaxy, allowing in only the light from its target, and the cartridges must be changed with each observation on the 2.5-meter Sloan Digital Sky Survey (SDSS) telescope at Apache Point Observatory in New Mexico.

The team plugs fiber optic cables into the holes by hand to siphon each galaxy's light into a spectrograph that can decipher its redshift and deliver a precise position.

Astronomy heralded the historic sky survey's start in 1998, saying it would amass 12 terabytes of publicly available data over the initial five years, which would rival all the content stored by the Library of Congress at the time. From first light to the SDSS III survey completed in 2014, this revolutionary project has been responsible for the most detailed 3-D maps of the universe.

And beyond the project's enormous success, it's also proved to be a harbinger of what's to come.

But SDSS will soon seem like pushing punch cards into computers. Mathis recently headed the operations group for Kitt Peak National Observatory's 4-meter Mayall Telescope south of Tucson, Arizona, where she oversaw instrument changes. And a truly incredible device is on its way. In mere months after its first light, projected for 2018, the new $70 million Dark Energy Spectroscopic Instrument (DESI) will surpass the monumental success of its predecessor.

When complete, it will allow astronomers to image galaxies up to 10 billion light-years away thanks to 5,000 fiber optic cables. Instead of a team drilling plates and hand-positioning cables, the fiber optics can be repointed via actuators in just 40 seconds.

"This instrument is so powerful that in its first night of observations, it will record more data than anyone else has at that kind of cosmological depth," says DESI Project Director Michael Levi of the Lawrence Berkeley National Laboratory.

But this seemingly massive new survey is actually small in comparison to what's on the horizon for astronomy. Big collaborations of scientists are set to consume even bigger budgets, forcing organizations overseeing older telescopes to make difficult decisions. Within a decade, five separate billion-dollar mega telescopes should open in Hawaii and across Chile, Africa, and Australia.

Astronomers typically get a few nights each year on a large telescope. The 8.4-meter Large Synoptic Survey Telescope (LSST) in Chile will view the entire visible sky twice a week for a decade. On any given night, it will collect more data than SDSS did in its first five years. That data will be immediately available online to anyone.

"We as astronomers are not used to working with machines like this," LSST scientist Mario Juric of the University of

The ivory tower housing Kitt Peak National Observatory's 4-meter Mayall Telescope stands tall over the Arizona desert, as it has for nearly five decades.

Washington told an audience of SETI Institute astronomers in 2014. "We were traditionally a really, really data-starved science. It used to be there were many theories, but no way to disprove them. If you had the telescope, that was the key differentiator for making it or not."

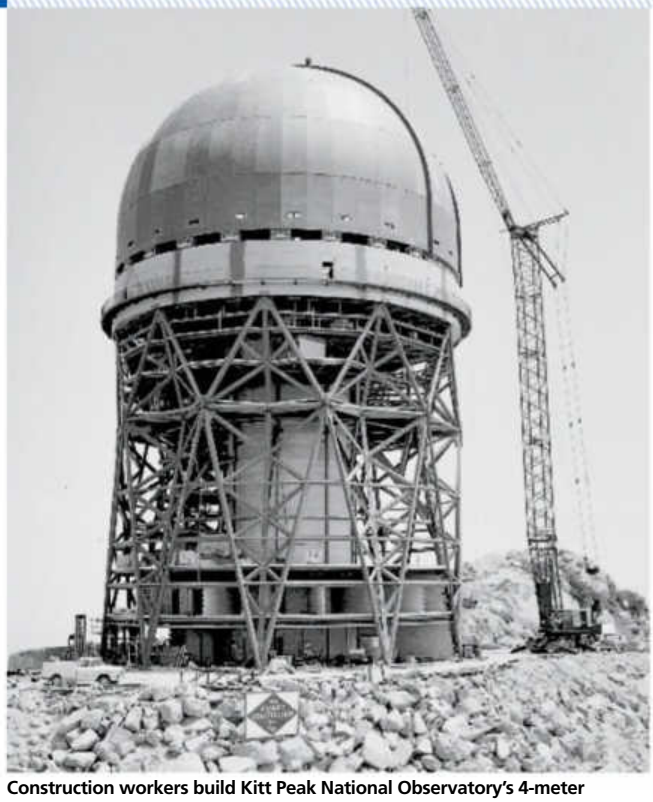
THE DEMOCRATIZATION OF ASTRONOMY

A century ago, wealthy and generous individuals helped form prestigious institutions that controlled the world's best telescopes. From Lick Observatory to Lowell, and from Yerkes to Palomar, astronomers with rich benefactors most often were the ones who made discoveries.

But in 1955, a panel of astronomers recommended constructing telescopes owned by taxpayers and open to all, regardless of affiliation. Like the national parks long before, this American idea allowed equal access. The National Science Foundation (NSF) called it their "open skies" policy. Time was distributed on the peer-reviewed worthiness of proposals.

Kitt Peak became the birthplace of the National Optical Astronomy Observatory (NOAO), and the 4-meter Mayall Telescope was its flagship. Construction began in 1968, the same year Apollo astronauts first circled the Moon. The idea eventually spread to include a network of American-owned and NSF-supported optical, radio, and solar telescopes across the country. As a result, the United States pushed to the forefront of astronomy.

Fast-forward to present day, and Kitt Peak remains a workhorse for the American astronomer. With its suite of telescopes, the observatory now provides a sum of 800 nights of research each year, with a little less than half of that happening on the Mayall. Still, the newest telescope on the mountain, the 3.5-meter Wisconsin-Indiana-Yale-NOAO (WIYN), is more than two decades old.



Construction workers build Kitt Peak National Observatory's 4-meter Mayall Telescope in June 1969.

The NSF now supports more than a dozen telescopes, with plans to spend billions of dollars for new instruments at some of the world's darkest sites. Veteran astronomers expect the most ambitious of these projects, LSST, will bring true transformation to the field, similar to that wrought by the Mayall some 50 years ago.

DESI is an order of magnitude improvement over the Sloan survey, but the Large Synoptic Survey Telescope will be like SDSS on steroids. It will record an epic 10-year movie of the entire southern sky out to an incredibly faint magnitude 24.5 — some 16 million times fainter than the naked eye can see. There will be no proposals for use, no competition for time. And this torrent of the cosmos will be unleashed online where absolutely anyone can access it as soon as LSST sees first light in 2022.

"When you think of a telescope, you typically think of something that's on a mountain, and then an astronomer goes there and sits at a computer and does something, maybe they'll look at their favorite object and go home," says Juric. "This is not the way this telescope is going to operate. It's practically a robot that sits on top of a mountain, and it does its thing."

Engineers expect 28 billion alerts over the course of LSST's life, letting astronomers know in real time when something changes from one image to the next, giving new hope for finding supernovae, comets, asteroids, galaxies, and who knows what else.

The stereotype of astronomers, like Edwin Hubble, as lone stargazers peering through an eyepiece hasn't been accurate since electronic detectors eliminated the need to look through a telescope. But the next generation of telescopes will eliminate the need to even visit such an instrument.

The scientific bounty will be unprecedented in astronomy — like when biologists unlocked the genome. The results also will create a new data challenge. For many astronomers, big data will end the already diminished need to actually visit a telescope.

THE PORTFOLIO REVIEW

To pay for new telescopes like LSST, the NSF has decided to let go of some of the old. In 2012, a portfolio review written by astronomers recommended the agency stop funding six telescopes, four of which sit atop Kitt Peak.

The group's report suggested ending NSF funding for Kitt Peak's Mayall, WIYN, and 2.1-meter telescopes, plus the McMath-Pierce Solar Telescope, run by the National Solar Observatory (NSO). The National Radio Astronomy Observatory (NRAO) operates the other two facilities recommended for closure: the Green Bank Telescope (GBT) in West Virginia, a radio dish that's the world's largest single steerable telescope; and the Very Long Baseline Array, a network of 10 radio dishes spread across the country. Combined, the facilities cost $20 million to run each year, or about 10 percent of the NSF's annual astronomy budget.

The report recommended spending that money on new projects like LSST and handing off the old instruments to other institutions. But that hasn't been an easy task because the old scopes are still producing new science, and universities who might be interested also are pressed for cash.

The report writers said the GBT, the newest of the NSF facilities on the chopping block, was exceptional in its resolution, but its science goals could also be done on other instruments, sometimes with better results. The radio telescope costs around $8 million per year to operate. That site has rallied support from the state's congressional leaders, who helped secure $1 million a year for West Virginia University to take a share of GBT time. Scientists also sent rebuttal letters touting the GBT's unique ability to study pulsars, which are being put to use by an international collaboration using NSF funds to search for gravity waves.

NOAO/AURA/NSF (2)

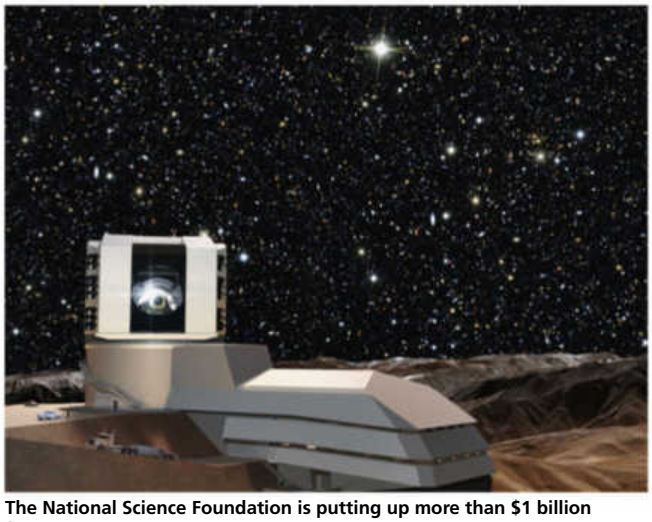
Scientists are after new funding sources for the National Radio Astronomy Observatory's Green Bank Telescope in West Virginia. The observatory is targeted to lose its current financial backing by 2017. So far, the National Science Foundation hasn't moved to divest.

Kitt Peak's McMath-Pierce Solar Telescope, the largest such instrument in the world, will close by 2017 unless another group agrees to take over.

The report also concluded that Kitt Peak's 1.6-meter McMath-Pierce Solar Telescope, dedicated in 1962 and currently the largest solar telescope in existence, should lose funding "as soon as possible." The facility has since been reduced to a $200,000 yearly budget, the minimal amount to maintain operations, with just one part-time staff operator.

"The telescope is an older facility, but in the past decade, we've averaged about 12 papers per year," says Matt Penn, an NSO associate astronomer. "If you calculate the price per paper, we're quite efficient."

Even the diminished funding will zero out by 2017, and so far no one has stepped up with funds to continue observing. Penn is hoping to find an organization or collaboration, maybe a collection of amateurs — really anyone — that can take over the facility. As it is, observing astronomers regularly run the telescope for themselves, and when something goes wrong, the NOAO staff often comes over to help out their sibling agency. If any of the instruments break, there's no cash to cover a fix.



The National Science Foundation is putting up more than $1 billion for the Large Synoptic Survey Telescope, which will record a movie of the entire southern sky every three days for a decade.

CLOCKWISE FROM TOP LEFT: NRAO/AURA; NOAO/AURA/NSF; TODD MASON, MASON PRODUCTIONS/LSST CORP.

And McMath isn't alone in its rapid shift to an uncertain retirement. The Dunn Solar Telescope in New Mexico is also slated to close in 2017. The NSF is unloading its Sun-watching scopes in preparation for a new behemoth, the $344 million Daniel K. Inouye Solar Telescope (DKIST) in Hawaii.

This 4-meter is giant for a solar scope and employs adaptive optics, a technological tool typically reserved for astronomers trying to see through Earth's turbulent atmosphere to far-off suns. Instead, the DKIST will reveal our nearest star in unprecedented detail.

Astronomers hope close-up views of solar surface features will unravel the mystery of our Sun's magnetism and lead to a new understanding of our active star.

But losing these major solar telescopes two years before the DKIST opens will leave a gap in astronomers' ability to watch the Sun in high resolution and study solar storms. Spacecraft can see the Sun in multiple wavelengths without the filter of Earth's atmosphere, but they have significantly worse views of our star than their much larger earthly counterparts. And because astronomers also regularly use the McMath at night to observe bright objects like the Moon and Mercury, other unique abilities will disappear without its long eye.

SAVED BY STEEL

Overall, Kitt Peak actually has had an easier time repositioning itself than most. Instead of closing or reducing operations, negotiations led to the mountain's two main telescopes getting major overhauls and new alliances of operators that will prime them to make pioneering discoveries.

"Things looked a little dire a few years ago when the NSF portfolio review came out and recommended divestment at Kitt Peak," says Observatory Director Lori Allen, who took over in 2013. "But through the diligent work of the NSF and the other federal agencies working closely with us, I think we've designed a future for both of these 4-meter telescopes."

In addition to the Mayall's makeover with DESI, the WIYN will be reborn as a high-tech exoplanet research

Engineers will remove the Mayall Telescope's top half and replace it with an elaborate system of lenses and fiber optic cables made to hunt dark energy. The 500,000-pound (225,000 kilograms) steel mount, designed in the late 1960s, makes it an ideal place for the large instrument.

instrument. The NSF will continue supporting the partnership with new funds from NASA to help answer another defining question of our age: Are we alone? The space agency will pay for an extreme precision radial velocity spectrometer called NN-EXPLORE, which will be put to use studying exoplanets around nearby stars. WIYN also will make follow-up observations of alien worlds seen by NASA's Transiting Exoplanet Survey Satellite, set for launch in 2018.

Kitt Peak's 2.1-meter telescope is in the process of being handed off to a consortium of universities for their own research. The team will install a robotic adaptive optics instrument already in use at Southern California's Palomar Observatory, where light pollution has compromised the starry skies. The device, called Robo-AO, will automatically subtract the twinkling of Earth's atmosphere.

"We've always been an open-access observatory and rightly so because we were funded entirely by the NSF for that purpose," Allen says. "Now we're in a situation where the NSF can no longer fund us at that level. If we want to continue doing frontline science, we have to start doing project science."

For the Mayall, its antiquated frame actually proved to be its saving grace. With minimal modification, the telescope can support an instrument that weighs as much as four Toyota Land Cruisers.

"The [portfolio review] timing was fabulous because the DESI instrument, it's big," Levi says. "It's the size and weight of a school bus — 10,000 kilograms [22,000 pounds]. It's heavy. We were actually looking for an older telescope, and the Mayall happens to be perfect because it's built of so much steel."

The telescope structure weighs half a million pounds (225,000kg) — two times heavier than the infamous Hughes H-4 Hercules airplane, or "Spruce Goose," and nearly as much as the world's largest current passenger aircraft, the Airbus A380. To make way for DESI, engineers must remove the Mayall's entire top end. "This thing is just massively over-engineered," Levi says. "It's insanely well built."

Another benefit of the Mayall is that it allows this new dark energy survey an unrivaled 8-square-degree field of view. DESI will tear through the night sky like a cosmic cookie cutter, stamping out circles 40 times bigger than the Full Moon with each of its estimated 10,000 observations.

THE DARK ENERGY MAP

DESI traces its origins to an SDSS project that examined galaxy structure in the early universe through the Baryon Oscillation Spectroscopic Survey (BOSS). Baryons make up most of our universe's matter in heavy particles like protons and neutrons. BOSS showed that this matter made sound waves and left imprints on the early universe, like pebbles tossed into a pond, creating fluctuations in the cosmic microwave background as the cosmos cooled enough for matter to form. These early fluctuations are called baryon acoustic oscillations, and they led to uniform voids between galaxies.

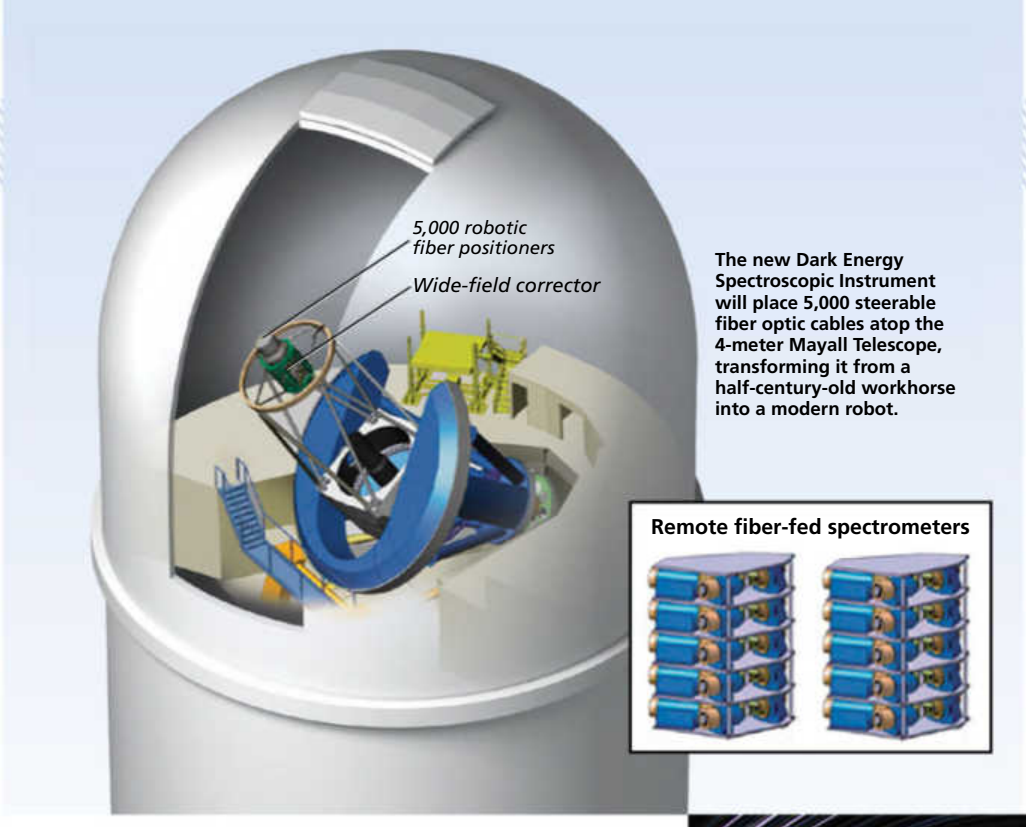
Astronomers use the oscillations as a cosmic ruler to measure the 3-D positions of objects billions of light-years away.

Whereas BOSS could gather 8,000 objects per night, DESI will knock off as many as 150,000. When the survey is complete, it will pinpoint the locations of some 25 million galaxies and quasars — active galactic cores — to produce

10 Telescopes Targeted to Lose Funding

NOAO 2.1-meter telescope	Arizona
Mayall 4-meter telescope	Arizona
WIYN 3.5-meter telescope	Arizona
McMath-Pierce Solar Telescope	Arizona
SOAR 4.1-meter telescope	Chile
NSO Integrated Synoptic Program	Multiple countries
Dunn Solar Telescope	New Mexico
Very Long Baseline Array	Spread across U.S.
Green Bank Telescope	West Virginia
Arecibo Observatory	Puerto Rico

NOAO/AURA/NSF



The new Dark Energy Spectroscopic Instrument will place 5,000 steerable fiber optic cables atop the 4-meter Mayall Telescope, transforming it from a half-century-old workhorse into a modern robot.

Technicians must drill a hole in Sloan Digital Sky Survey fiber optic cable plug plates for each individual galaxy they observe. The Dark Energy Spectroscopic Instrument does away with this labor-intensive process, thanks to steerable fiber optic cables.

the most comprehensive picture of our universe ever.

The project is a nod to the big data future of astronomy, as well as what's possible for aging observatories looking to redefine their relevance in light of new technology.

But when the Mayall is reborn in 2018, it will cease to be an open skies instrument. DESI includes 178 senior scientists from around the world, as well as their postdocs and students. This collaboration will get the first look at data before it's released. Pending continued congressional approval, the Department of Energy will foot most of the bill, with additional support from the Gordon and Betty Moore Foundation and the Heising-Simons Foundation.

"These large statistical surveys require ferocious quantities of computational power and databases and huge, long-running jobs that are not accessible to an individual," Levi says. "One person couldn't do this experiment. One person couldn't take the data and analyze it. Ten people couldn't. So now what do you do?"

Tod Lauer has been at the forefront of this culture change. The NOAO astronomer remembers pulling tables out of science journals as an undergraduate and plotting the points with a pencil. He went on to help adapt the first CCD cameras to telescopes, which ultimately led to surveys like SDSS. And while he was still a young scientist, he submitted the first paper using data from the Hubble Space Telescope. He still works with Hubble and several large surveys today, including NOAO's existing Dark Energy Survey on the Mayall's twin telescope in Chile.

Lauer says computer skills like learning to visualize data sets and employ machine learning are more important than ever for astronomers. He recently organized a workshop in Tucson called "Tools for Astronomical Big Data" and was shocked when 130 people showed up.

CLOCKWISE FROM TOP LEFT: ROEN KELLY, AFTER LAWRENCE BERKELEY NATIONAL LABORATORY (2); D. LONG/SDSS-III; P. MARENFELD AND NOAO/AURA/NSF

Star trails circle the dome of the 4-meter Mayall Telescope, which will house the Dark Energy Spectroscopic Instrument by 2018 if Congress approves final funding.

"We're looking ahead to these tremendously large surveys like LSST, so we can see what's on the horizon, but with our dark energy survey, we've got the problems in front of us right now," Lauer says. "We need to ride these waves and get the community ready for the next big things."

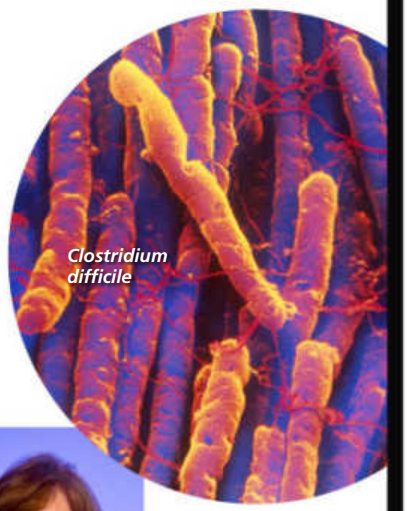
Allen, Kitt Peak's director, thinks her observatory will be ready for those next big things. Tucson was recently selected for the NOAO's new Data Lab, built to help astronomers utilize observations from the many surveys. And revitalization on the mountain should also carve a niche in this big data era for decades to come. D

Eric Betz *is an associate editor of* Astronomy. *He is on Twitter,* ***@ericbetz****.*

Inside an Astronaut's Guts

Each of us has thousands of microbes living under and on our skin. What happens when we take them to space?

BY **SARAH SCOLES**


Clostridium difficile

"Is your spaceship going to be manned?" Pamela Contag once asked a rocket scientist at a symposium of the 100 Year Starship (100YSS) project, a NASA- and DARPA-funded group whose goal is to make interstellar travel possible in a century. Yes, he said, his rocket would have a crew. Contag smiled, then lowered the boom: Microbes could ruin the whole mission, she told him.

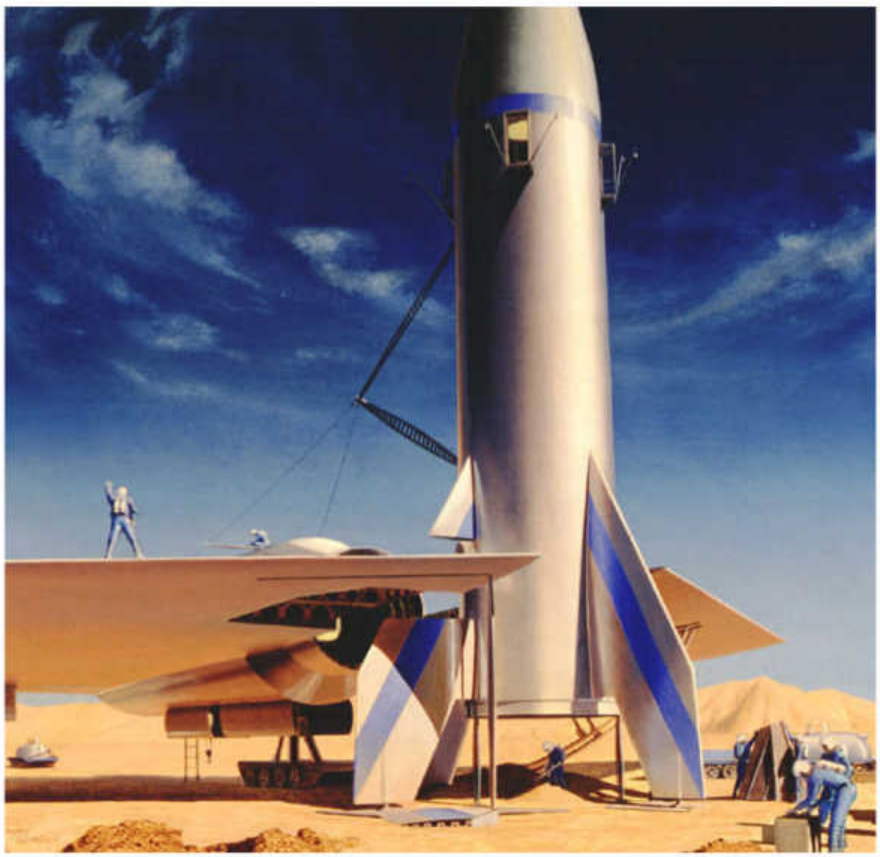
While other scientists at the 2014 symposium gave hopeful presentations about antimatter propulsion and moon mining, Contag, a microbiologist, began hers with, "Warning: I'm going to bring the mood down." We know almost nothing, she continued, about how long-term spaceflight affects the microorganisms inside us.

These microbes outnumber "our" cells 10 to 1, and we're only beginning to learn how much influence they wield. Depending on their composition, those bugs can keep disease away or cause illness, slim us down or fatten us up, even induce depression or calm anxieties — all facts we have discovered in the past decade.

These bugs will change us in space, in ways we can't predict, given that the longest anyone has spent in space is 2.2 years. Maybe they'll result in obese, depressed astronauts. And being locked in a metal box rarely makes people less depressed or anxious, conditions that an off-kilter microbial colony could exacerbate. They could even leave the crew violently ill and dying. Infectious diseases spread easily in closed containers. An immune system compromised by unforeseen microbial changes would only make matters worse.

A typical human's microbiome, the collection of tiny organisms that live on and inside the body, may contain up to 10,000 species. "They're all doing something different, and they're all connected," Contag says. These


Pamela Contag argues that one of the keys to long-term spaceflight is understanding our microbiome, the set of microorganisms that make our bodies their home.


We've been dreaming of visiting Mars since the 1950s, but even such a relatively short trip could wreak havoc on our microbiomes.

FROM TOP: DAVID M. PHILLIPS/SCIENCE SOURCE; RICK GILBERT/SKYHOOKENT FOR SPRINGBOARD ENTERPRISES; REPRODUCED COURTESY OF BONESTELL LLC

Limit one per customer at this special low price!

Get a 2016 American Eagle Silver Dollar *at our cost!**

You can't purchase this Uncirculated American Eagle silver dollar directly from the U.S. Mint. But you can now purchase the official 2016 U.S. silver dollar from Littleton Coin Company at our cost – and with FREE shipping to your home!

ONLY $16.81 *with FREE Shipping!*

The beautiful and sought-after $1 American Eagle is over 99.9% pure silver and carries the same design as the popular "Walking Liberty" silver coins of 1916-47. You'll also receive our fully illustrated catalog, plus other fascinating selections from our Free Examination Coins-on-Approval Service, from which you may purchase any or none of the coins – return balance in 15 days – with option to cancel at any time. Don't delay – order your 2016 American Eagle silver dollar *at our cost today!*

Limited-Time Offer!

NEW RELEASE!

- ★ **One ounce of 99.93% pure silver!**
- ★ **Beautiful mint Uncirculated condition!**
- ★ **2016 marks the 31st year of issue of the American Eagle series**
- ★ **Limited-time offer for new customers**

Due to fluctuations in the coin market, prices are subject to change.
** "At our cost" reflects market price as of December 1, 2015.*

FREE Gift!

when you order by deadline

Complete 4-Coin Uncirculated Set of 2009 cents, featuring special designs honoring the bicentennial of Lincoln's birth!

45-Day Money Back Guarantee of Satisfaction

IMPORTANT NOTICE:
Order Deadline: 12:00 Midnight, April 30, 2016

Special Offer for New Customers Only

Get a 2016 American Eagle Silver Dollar *at our cost!*

☑**YES!** Please send me the Uncirculated American Eagle Silver Dollar at Littleton's cost (limit 1). Plus, send my **FREE** Uncirculated 2009 4-Coin Lincoln Cent Set (one per customer, please).

Limit One: $ 16.81

Shipping & Handling: $ FREE!

Method of payment:
❑ Check or Money Order payable to Littleton Coin Co.

Total Amount: $ 16.81

❑VISA ❑MasterCard ❑American Express ❑Discover Network

Card No. Exp. Date ____/____

Name _____
Please print your complete name and address clearly

Address _____ Apt# _____

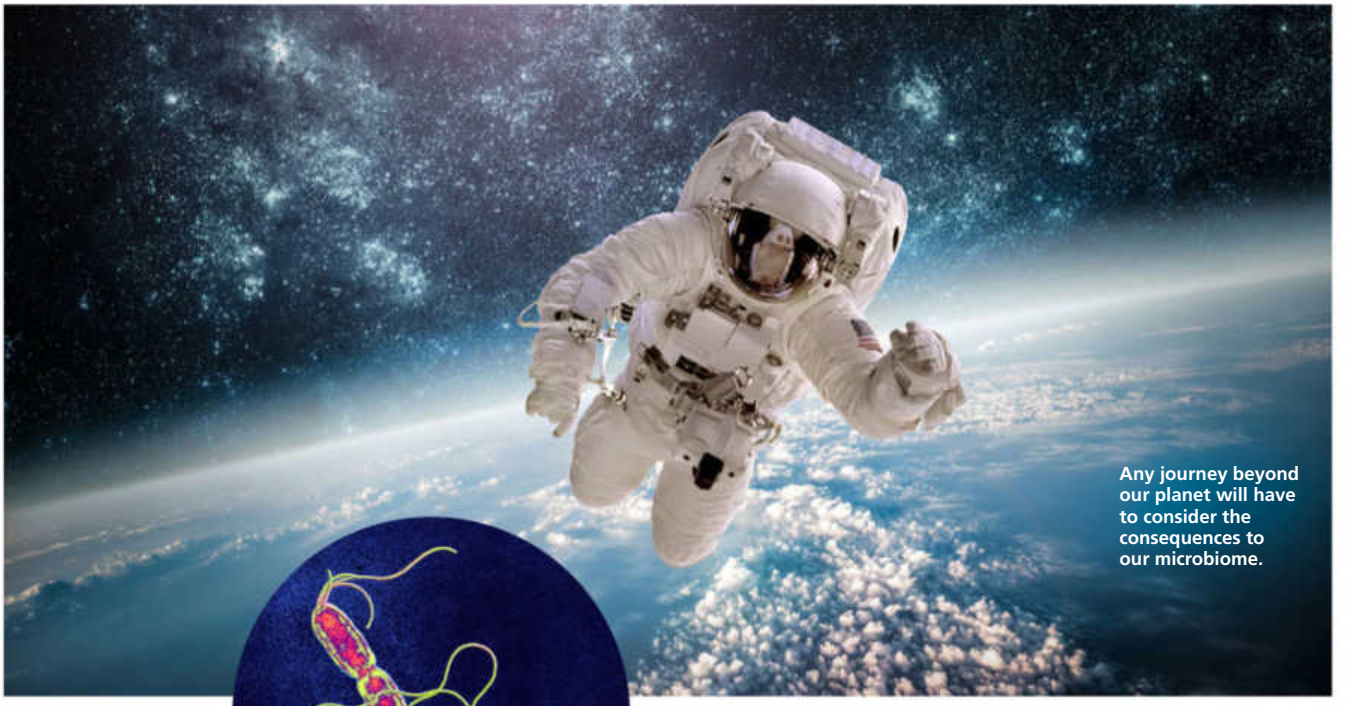
City _____ State _____ Zip _____

E-Mail _____

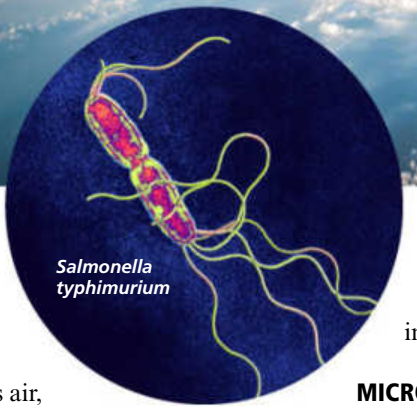
Please send coupon to:

Littleton Coin Company®
Dept. 4BT407
1309 Mt. Eustis Road
Littleton NH 03561-3737

America's Favorite Coin Source • TRUSTED SINCE 1945



Any journey beyond our planet will have to consider the consequences to our microbiome.



Salmonella typhimurium

organisms — and we ourselves — are also connected to our environment. On a spaceship, "environment" means air, metal, silicon, plants, water and other passengers, each with its own microbe collections. The microbes clinging to those people, places and things will become part of each astronaut.

It makes you wonder, Contag continues, "What, really, is a human?" If the organisms that live inside us can change our immunity, appearance and mental stability, they aren't just part of us: They *are* us.

The audience at Contag's 100-Year Starship talk — a mix of rocket scientists, science fiction authors, psychologists, engineers and astrophysicists — stared wide-eyed at her slide deck. For the most part, they ponder things like spacesuit design and small-population reproduction. They don't know what to do with this so-called microbiome, but they'll have to figure it out if we're going to spend much time together in space.

MICROBE MAVEN

Contag first looked to the stars as a young child. That led her to a career in science, studying microbial physiology and human immunology. In 2012 she met former astronaut and 100YSS leader Mae Jemison at Springboard Enterprises, an organization that works to build technology-oriented companies led by women, and her interest in space found a new outlet. Jemison knew from Contag's history of founding startups — biofuels, cancer drugs, molecular imaging — that she was a quick study and easily intrigued. When Jemison suggested she chair the Life Sciences track at 100YSS, Contag didn't hesitate.

Contag was already running the Molecular Sciences Institute, a biotech nonprofit, in a spartan office building in Milpitas, Calif. "MolSci" provides lab space and mentorship to biologists whose ideas don't fit within academia but could have a home in industry. Since beginning her Starship research, she's also started investigating how microbes can change depending on their environment, including space, and how those changes affect human beings.

Those aren't trivial adjustments. "During a space flight, astronauts are exposed to stressors, such as radiation, microgravity, stress and changes in the diet," says Hernán Lorenzi, a bioinformatician with the J. Craig Venter Institute and principal investigator of the first study of actual microbiomes in space and on the human immune system (analyzing space station astronauts). "Long-term exposure to these stressors may alter the composition of the crew microbiome at a level that poses a risk to their health and compromises their mission," Lorenzi says.

Mae Jemison

FROM TOP: ANDREY ARMYAGOV/SHUTTERSTOCK; KWANGSHIN KIM/SCIENCE SOURCE; RITA QUINN/GETTY IMAGES

HARBOR FREIGHT
QUALITY TOOLS AT RIDICULOUSLY LOW PRICES

QUALITY TOOLS LOWEST PRICES EVERYDAY

How Does Harbor Freight Sell GREAT QUALITY Tools at the LOWEST Prices?

We have invested millions of dollars in our own state-of-the-art quality test labs and millions more in our factories, so our tools will go toe-to-toe with the top professional brands. And we can sell them for a fraction of the price because we cut out the middle man and pass the savings on to you. It's just that simple! Come visit one of our 600+ Stores Nationwide.

SUPER COUPON

20% OFF ANY SINGLE ITEM

Limit 1 coupon per customer per day. Save 20% on any 1 item purchased. *Cannot be used with other discount, coupon or any of the following items or brands: Inside Track Club membership, extended service plan, gift card, open box item, 3 day parking lot sale item, compressors, floor jacks, saw mills, storage cabinets, chests or carts, trailers, trenchers, welders, Admiral, CoverPro, Daytona, Diablo, Franklin, Hercules, Holt, Jupiter, Predator, Stik-Tek, StormCat, Union, Vanguard, Viking. Not valid on prior purchases. Non-transferable. Original coupon must be presented. Valid through 6/2/16.

45799562

SUPER COUPON

FREE WITH ANY PURCHASE

PITTSBURGH 1" x 25 FT. TAPE MEASURE

LOT 69031/69030 shown

$4.97 VALUE

LIMIT 1 - Cannot be used with other discount, coupon or prior purchase. Coupon good at our stores, HarborFreight.com or by calling 800-423-2567. Offer good while supplies last. Shipping & Handling charges may apply if not picked up in-store. Non-transferable. Original coupon must be presented. Valid through 6/2/16. Limit one FREE GIFT coupon per customer per day.

45816101

WOW SUPER COUPON

RAPID PUMP® 1.5 TON ALUMINUM RACING JACK

PITTSBURGH

- 3-1/2 Pumps Lifts Most Vehicles
- Weighs 32 lbs.

SAVE $60

Customer Rating

LOT 69252 68053/62160 62496/62516 60569 shown

$59.99 ~~$89.99~~

comp at $119.99

45766614

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 6/2/16. Limit one coupon per customer per day.

SUPER COUPON

60 LED SOLAR SECURITY LIGHT

Bunker Hill Security

SAVE 54%

LOT 62534 69643 shown

Customer Rating

Includes 6V, 900 mAh NiCd battery pack.

$31.99 comp at $69.99

45806911

LIMIT 3 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 6/2/16. Limit one coupon per customer per day.

SUPER COUPON

7 FT. 4" x 9 FT. 6" ALL PURPOSE WEATHER RESISTANT TARP

SAVE 57%

LOT 69115/69137 69249/69129/69121 877 shown

Customer Rating

$3.99 comp at $9.38

45761770

LIMIT 7 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 6/2/16. Limit one coupon per customer per day.

WOW SUPER COUPON

8750 PEAK/7000 RUNNING WATTS 13 HP (420 CC) GAS GENERATORS

PREDATOR GENERATORS

Customer Rating

SUPER QUIET

LOT 68530/63085 63086/69671 shown

LOT 68525/69677 63087/63088 CALIFORNIA ONLY

- 76 dB Noise Level

SAVE $459

$540 ~~$599.99~~ comp at $999

45785823

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 6/2/16. Limit one coupon per customer per day.

SUPER COUPON

ELECTRIC CHAIN SAW SHARPENER

CHICAGO ELECTRIC POWER TOOLS

4-1/4" grinding wheel included.

Customer Rating

SAVE 40%

LOT 61613/68221 shown

$29.99 comp at $49.99

45794934

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 6/2/16. Limit one coupon per customer per day.

SUPER COUPON

TORQUE WRENCHES

PITTSBURGH PRO

- Accuracy within ±4%

Customer Rating

SAVE 60%

Item 239 shown

YOUR CHOICE $11.99 comp at $29.99

DRIVE	LOT
1/4"	2696/61277
3/8"	807/61276
1/2"	62431/239

45794116

LIMIT 6 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 6/2/16. Limit one coupon per customer per day.

SUPER COUPON

US GENERAL PRO

26" 16 DRAWER ROLLER CABINET

- 1060 lb. capacity
- 14,600 cu. in. of storage

LOT 61609 67831 shown

Customer Rating

SAVE $633

$319.99 comp at $952.99

45776245

LIMIT 3 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 6/2/16. Limit one coupon per customer per day.

SUPER COUPON

BADLAND

SAVE $200

2500 LB. ELECTRIC WINCH WITH WIRELESS REMOTE CONTROL

Customer Rating

$59.99 comp at $259.99

LOT 61258 shown 61840/61297/68146

45774514

LIMIT 3 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 6/2/16. Limit one coupon per customer per day.

SUPER COUPON

1500 WATT DUAL TEMPERATURE HEAT GUN (572°/1112°)

drillmaster

LOT 63104/62340/62546/96289 shown

Customer Rating

SAVE 70%

$8.99 comp at $29.97

45797513

LIMIT 7 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 6/2/16. Limit one coupon per customer per day.

SUPER COUPON

2.5 HP, 21 GALLON, 125 PSI VERTICAL AIR COMPRESSOR

CENTRAL PNEUMATIC

LOT 69091/67847 shown 61454/61693/62803

Customer Rating

SAVE $349

$149.99 ~~$179.99~~ comp at $499

45801292

LIMIT 3 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 6/2/16. Limit one coupon per customer per day.

SUPER COUPON

1 TON CAPACITY FOLDABLE SHOP CRANE

PITTSBURGH

SAVE $169

LOT 69445/93840 61858/69512 shown

- Includes Ram, Hook and Chain

$99.99 comp at $269

45797946

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 6/2/16. Limit one coupon per customer per day.

SUPER COUPON

NEW

SAVE 76%

29 PIECE TITANIUM NITRIDE COATED HIGH SPEED STEEL DRILL BIT SET

LOT 5889 62281 61637 shown

$13.99 ~~$19.99~~ comp at $59.97

45817067

LIMIT 6 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 6/2/16. Limit one coupon per customer per day.

- 100% Satisfaction Guaranteed
- Over 30 Million Satisfied Customers
- No Hassle Return Policy
- Lifetime Warranty On All Hand Tools
- 600+ Stores Nationwide
- HarborFreight.com 800-423-2567

We already know how some microbes, outside the human body, alter their behavior in space. In seven separate space shuttle missions, researchers found that *E. coli* reproduced twice as fast. And *Salmonella typhimurium*, which could lurk in the food astronauts bring aboard, became more virulent and deadly after just a few days on shuttle mission STS-115 — imagine the stomach-virus epidemics that have plagued cruise ships, but compounded by the challenges of outer space. Medicines have shorter shelf lives, too, so the pills astronauts leave with might be ineffective by the time they return. It's not all bad, though: The normally deadly *Staphylococcus aureus* quickly becomes benign in microgravity.

We know only the basics of how these microbes change: Individual genes can turn on and off in different circumstances, and space is an awfully different set of circumstances than Earth. While its DNA remains the same, a microbe's ability to "read" a given DNA sequence can change unpredictably. This, of course, only hints at what might happen to the microbes *inside* astronauts' bodies.

SPACE ECOLOGY

This dynamism was what initially drew Contag to study the microbiome in the first place. The first organism she ever studied, at grad school in 1982, was the bacteria genus *Clostridium*. In the soil, it's benign. But if it gets under our skin, it morphs into a disease. "'Why would something be pathogenic in the human body and not outside?'" she wondered.

She investigated how molecular pathways talked to each other and connected the microbe with its environment. *Clostridium* changes a lot with a change in environment: If nutrients were low, it would form a spore; a high pH meant it would produce acid. The bacterium's behavior would also change, turning from Jekyll to Hyde. "I started looking at the turning on and off," she says, focused on the connection between us and our surroundings. "I realized we're in the middle of this triangle," she says: food (which ultimately comes from soil), water and our health.

Astronauts will have to understand "their" microbes, but they'll also have to deal with those in the flora, dirt, air and hydration of their spaceships.

Contag has planted her research in the middle of that triangle. Other scientists might call Contag unfocused, but she insists she just loves complex problems. After her *Clostridium* chase, she dove into microbiology research. But it's only in the past few years that scientists like Contag could look at the actual DNA of these (sometimes still nameless) organisms. The next step, she says, is to understand how the microbiome acts as a unit, and with the human host, to create health benefits — and how to fix someone's microbiome when it's broken.

Space agencies are getting into the microbiome game, too. NASA has teamed up with genomics research firm the J. Craig Venter Institute to fund Lorenzi's study of space station astronauts. For six months starting in September 2014, people in orbit provided Lorenzi's team gifts of feces, saliva and blood. Back on Earth, researchers are now combining the samples' biological baggage with environmental readings, like temperature and humidity, mashing them up to tell a full story of how circumstances affect the microbe population inside the digestive tract. And last March, the space agency began a twin study comparing the microbiome of astronaut Scott Kelly with his Texas-based twin (and former astronaut) Mark Kelly. What we learn from these and future studies will be the first small steps allowing Starship travelers to make giant leaps into space.

CLOSED LOOP

Astronauts will have to understand "their" microbes, but they'll also have to deal with those in the flora, dirt, air and hydration of their spaceships — the same triangulated elements that drew Contag to molecular biology in the first place.

"Microbes are responsible for the carbon cycle and the nitrogen cycle," which let us breathe and plants photosynthesize, respectively, Contag says. "If we screw that up, it does not look good for the space colony."

To truly begin to study this topic, she wants to add a new triangle within Earth's interconnected triangle. "We need to create outer space here on this planet," she says. Before we can create a real starship (one that isn't full of sick astronauts), we should create a closed ecosystem on Earth — a hermetically sealed, self-sustaining biosphere. We've tried this before, but it's never been successful on a large level. It must provide everything inhabitants need, from oxygen to spare parts to probiotics, without input from the outside world. Once we can handle that, Contag says, we'll be on our way to transforming a spaceship into its own triangle — in some sense, its own planet.

And so Contag and other scientists will boldly go where no one has gone before: into the world of the microcosmonauts. After all, their world is our world. If humans hope to live for long inside a spaceship, we will have to draw a new triangle, and learn how to coexist. D

Sarah Scoles *is a freelance science writer in Berkeley, Calif.*

CLASSIFIEDS

BOOKS

SCIENCE BREAK THROUGH
Research Report: Electricity and Gravity, Tornadoes and Huricanes, Other Phenomena. Visit: www.smashwords.com/books/view/579120

TRAVEL

AMAZON RAINFOREST
Award-winning lodge in Tamshiyacu-Tahuayo Reserve, shown to have the world's greatest diversity of primates. Customized itineraries, daily departures. 1-800-262-9669. Visit: www.perujungle.com

Discover MARKETPLACE

Amphibious Assault

In 1952, a plague of frogs struck a small Wisconsin town. Then the tide turned against *Lithobates pipiens*.

BY **JACK EL-HAI**

PATRICK FARICY

One spring six decades ago, in the ponds and marshes along a western arm of Lake Michigan, about 25 miles north of the city of Green Bay, Wis., the northern leopard frog *Lithobates pipiens* was busy breeding. The males trumpeted sex calls that vaguely sounded like, "'ere I am," followed by croaks of "rah-rah-rah" when they sensed females nearby. The females responded with their own throaty grunts.

The outcome of this noisy annual ritual was a lot — an awful lot — of fertilized eggs attached to plants or afloat in the waters of the marshes. During a normal breeding season, the lake would recede and the water would dry up or grow shallow, allowing only about 1 percent of the spawn to survive and mature.

A different scenario played out in 1952. The water of Green Bay, which normally floods in the spring, remained at a high level into the summer, and the wind kept whipping water into the adjoining marshes and ponds. Bayside roads crumbled from wetness, and shoreline homes became uninhabitable. But amphibians laid their eggs as usual.

As a result, conditions were fantastic for frog eggs: About three times the normal number of eggs hatched and released tadpoles that grew into frogs.

And these young northern leopard frogs were hungry, too hungry for the wetlands to support in such numbers. In search of grasshoppers, crickets, mosquitoes, snails or anything resembling sustenance, the frogs — 175 million strong — left the marshes and hopped toward Oconto, a quiet nearby county seat that was home to about 5,000 people. Once the frogs arrived en masse, they outnumbered the people 35,000 to 1.

INVASION OF THE LEOPARD FROGS

Thus began a nightmarish ordeal in which the most common amphibian in the region became way, way too common. Sleepy little Oconto resembled the set of one of the horror films for which the 1950s were so well known. Frogs filled the streets of the former lumber town, encircled homes and set the air throbbing with their massed croaking. Eli Waldron, a native of the area writing for *The New Yorker*, described loud and chilling rustlings in the grass, car trips marked by the resonant explosions of amphibians being squashed under the tires, lawn mowers that blew out sprays of severed frog parts, high mounds of frogs dotting the landscape, dogs driven wild and the terror of one resident who pointed a flashlight out his window at night to illuminate "a million shining little eyes. … It made the hair bristle on the back of his neck."

For more than a week, Oconto was a town overrun. Frogs were the main topic of conversation and the main obstacles underfoot. People survived by joking about having frogs' legs for dinner and ways to make money off the unexpected amphibious assault.

Gradually, though, as the summer wore on, the leopard frogs retreated, and peace came back to the people of Oconto. In the outlying ponds and marshes, however, frogs still ruled in massive numbers and made deafeningly cacophonous music as predatory herons, gulls and crows grew fat.

This was not the first time an overabundance of wildlife had beleaguered local residents. In 1893, the *Milwaukee Journal* reported on an infestation of pine snakes in nearby Oconto Falls that forced residents to catch and slaughter the reptiles in large numbers. Such a population boom, known to ecologists as overshoot, occurs when a sudden rise in a species's numbers exceeds the environment's capacity to support the increase. It can happen in temporarily optimal conditions in which disease or predators vanish, food is bountiful or breeding becomes spectacularly successful. It can appear among all sorts of creatures, from microorganisms to vertebrates.

But among instances of overshoot, the Oconto frog invasion hit the nearby humans especially hard. From their perspective, it appeared to rival the biblical plague that helped persuade the Egyptians to free the Israelites, and it may still rank as the most dramatic population spike of frogs in our nation's history. (A smaller-scale eruption of about 1 million eastern spadefoot toads occurred at Shol Pond in Florida's Ocala National Forest in 2000.)

Even so, nobody in 1952 should have been surprised to see abundant northern leopard frogs in Wisconsin or anywhere in much of the rest of the northern and western United States. At that time, the species abounded. Hunters who harvested the frog to sell always found plenty to fill their crates. Compared with other common frogs, people often found the northern leopard frogs handsome, intelligent-looking and even "aristocratic." Their slender and long-legged green- or brown-spotted bodies were long familiar not only outdoors, but also on the dissection tables of high school science labs around the country.

Such a population boom, known to ecologists as overshoot, occurs when a sudden rise in a species's numbers exceeds the environment's capacity to support the increase.

BOOM TO BUST

During the 1970s and '80s, though, it wasn't dissection but the loss of habitat, disease and pollution that combined to greatly reduce the number of northern leopard frogs throughout their range. They are now endangered or threatened in many regions of North America.

"Today, if we find a site with 30 breeding females, that's healthy," says Lea Randall, a population ecologist and biologist who leads a northern leopard frog study program for the Center for Conservation Research at the Calgary Zoo. In contrast, she estimates that 50,000 breeding females would have been needed to produce the army of young frogs that descended upon Oconto. "And it would have taken two or three years of steady water levels to produce those numbers," Randall says.

In some areas of the U.S. and Canada, the population of northern leopard frogs is no longer in free-fall decline. "They still can be locally abundant, and they're still fairly common in Wisconsin," Randall says. "But it's unlikely that a population explosion of the kind that took place in Oconto could ever happen again. The base populations are just so much smaller than they used to be, despite all the work done to try to re-establish populations. The most of these frogs that I've ever seen at one site is 800."

The 1952 plague intrigues her, though. "I'd be interested in its effect on the surrounding ecosystem. I've read that there were not many mosquitos around Oconto that year. I'd love to find out the effects on the frog's predators — on birds, coyotes and fish," she says. The ironies of a dramatic population spike within a frog species now considered threatened do not escape her. "It's sobering to consider that a species once so numerous can now be faced with extinction. Any species that we take for granted can go extinct if we don't try to conserve it."

Not many people in Oconto can remember the great frog invasion, but street and place designations like Frog Pond Road and Frog Lake remain to jog the memories of old-timers. No matter how stupefying and unnerving the recurrence of such an event would be to many, it would be a good sign that a once-mighty amphibian — and a familiar old friend of the people of North America — is again on the march. Or the hop. D

The handsome leopard frog was once common in the U.S.

Jack El-Hai *frequently writes about history, medicine and science. His most recent book is* The Nazi and the Psychiatrist: Hermann Göring, Dr. Douglas M. Kelley, and a Fatal Meeting of Minds at the End of WWII.

Your Back

BY **GEMMA TARLACH**

Ancient medical texts from Egypt to China (above) include remedies for back problems, which have been a scourge of our species.

1 Thanks to evolution, your back is a marvel of load-bearing support and flexibility — and kind of a mess. Our species is prone to back pain, for example, because our ancestors' imperfect transition to upright walking essentially took a spine similar to that of our nearest living relatives, knuckle-walking chimpanzees, and forced it vertical with piecemeal adaptations. **2** A 2015 study found that some people are, well, chimpier than others. Humans prone to certain back problems have vertebrae closer in shape to those of a chimpanzee than those of pain-free humans. **3** Regardless of shape, you might have more (or fewer) of the bones than your neighbor. Not everyone has the standard 33 vertebrae: From top to tail, that's seven cervical, 12 thoracic, five lumbar, five sacral and four coccygeal. **4** The number of vertebrae in individual *Homo sapiens* actually varies between 32 and 35, with the biggest range of difference in the pelvic area. **5** The four natural curves in our spines develop at different times. Both the thoracic (midback) and sacral (pelvic), which develop early in embryos, curve outward. **6** The other two curves, which bend inward, become more pronounced at key points in infant development: the cervical curve, when a baby can hold up its head; and the lumbar, when the li'l tyke begins to walk. **7** Every doctor who's ever examined you puts that ice-cold stethoscope on your triangle of auscultation, a quiet zone in between three major muscles near the base of your shoulder blade, where it's easier to hear your lungs. **8** Lower back pain, our most common backache, may not have been as big a deal for our Neanderthal cousins. A 2008 study in the *European Spine Journal* found that the lower spines of two adult Neanderthals showed little of the degeneration associated with a life of heavy physical activity, which we believe they experienced. **9** The secret to Neanderthals' better back health is apparently a combination of heavier musculature supporting their spines and lumbar kyphosis, a reverse curvature of the lower spine that, in our species, is considered abnormal. **10** The oldest known tattoos, including two on his back, belong to the famous 5,300-year-old Otzi the Iceman, found in the Italian Alps in 1991. **11** Some researchers theorize that Otzi's "ink" (actually soot) mapped out acupuncture treatments intended to ease a variety of ailments. **12** Most other ancient tattoos, many of which are on the back, appear to be symbolic and represent status or specific achievements, such as the elaborate animals of Siberia's 2,500-year-old Pazyryk mummies. **13** Bum backs, and remedies for them, have been recorded in the earliest medical documents. An ancient Egyptian scroll known as the Edwin Smith Surgical Papyrus, named after the archaeologist who purchased it in 1862, explains how to diagnose a "pulled vertebra." Sadly, only partial instructions for treatment are included. **14** The Egyptian scroll's author may have been concerned with fixing pulled vertebra, but by 2700 B.C., the Chinese were practicing intentional spinal manipulation. **15** Back-cracking was widespread throughout the ancient world — for better or worse. Hippocrates, for example, advocated strapping someone with an abnormally curved spine to a ladder, and then dropping the ladder (and patient) from a height. Don't try this at home, kids. **16** The modern practice of chiropractic began when Daniel David Palmer, a self-styled "magnetic healer," claimed to have restored the hearing of a deaf man by popping one of his vertebra back into place in 1895. **17** Palmer believed that a back out of whack — "subluxation," or vertebral misalignment — causes 95 percent of diseases. **18** A 2012 white paper by the Institute for Science in Medicine, however, declared, "There is no scientific evidence that chiropractic subluxations exist or that their purported 'detection' or 'correction' confers any health benefit." Ouch. **19** It's commonly believed the saying "watch your back" derives from military tactics, but the Oxford English Dictionary doesn't, ahem, back up this claim: It notes "watch your back" appears first in the 1949 Western novel *Milk River Range* by Lee Floren. **20** Disagree? Hey, we're just telling you what's in the OED so, you know, get off our backs (a saying with roots in the 17th century). D

Senior Associate Editor ***Gemma Tarlach*** *thinks Triangle of Auscultation is a great name for a band she wouldn't like.*

DISCOVER (ISSN 0274-7529, USPS# 555-190) is published monthly, except for combined issues in January/February and July/August. Vol. 37, no. 2. Published by Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187-1612. Periodical postage paid at Waukesha, WI, and at additional mailing offices. POSTMASTER: Send address changes to DISCOVER, P.O. Box 62320, Tampa, FL 33662-2320. Canada Publication Agreement # 40010760. Back issues available.

Introducing ***The new and revolutionary*** **Jacuzzi® Hydrotherapy Shower.**

AGING = PAIN

For many, arthritis and spinal disc degeneration are the most common source of pain, along with hips, knees, shoulders and the neck. In designing the Jacuzzi Hydrotherapy Shower, we worked with expert physicians to maximize its pain relieving therapy by utilizing the correct level of water pressure to provide gentle yet effective hydrotherapy.

JACUZZI® SHOWER = RELIEF

Four Jacuzzi® ShowerPro™ Jets focus on the neck, back, hips, knees and may help ease the pain and discomfort of:

- Arthritis
- Circulation Issues
- Aches and pains
- Neuropathy
- Sciatica
- Inflammation

The Jacuzzi® Hydrotherapy Shower provides a lifetime of comfort and relief… safely and affordably.

As we age, the occasional aches and pains of everyday life become less and less occasional. Most of us are bothered by sore muscles, creaky joints and general fatigue as we go through the day- and it's made worse by everything from exertion and stress to arthritis and a number of other ailments. Sure, there are pills and creams that claim to provide comfort, but there is only one 100% natural way to feel better… hydrotherapy. Now, the world leader in hydrotherapy has invented the only shower that features Jacuzzi® Jets. It's called the Jacuzzi® Hydrotherapy Shower, and it can truly change your life.

For over 50 years, the Jacuzzi® Design Engineers have worked to bring the powerful benefits of soothing hydrotherapy into millions of homes. Now, they've created a system that can fit in the space of your existing bathtub or shower and give you a lifetime of enjoyment, comfort and pain-relief. They've thought of everything. From the high-gloss acrylic surface, slip-resistant flooring, a hand-held shower wand, a comfortable and adjustable seat, to strategically-placed grab bars and lots of storage, this shower has it all.

Why wait to experience the Jacuzzi® Hydrotherapy Shower? Call now… it's the first step in getting relief from those aches and pains.

Call toll free now to get your FREE special report "Tips on Living to be 100"

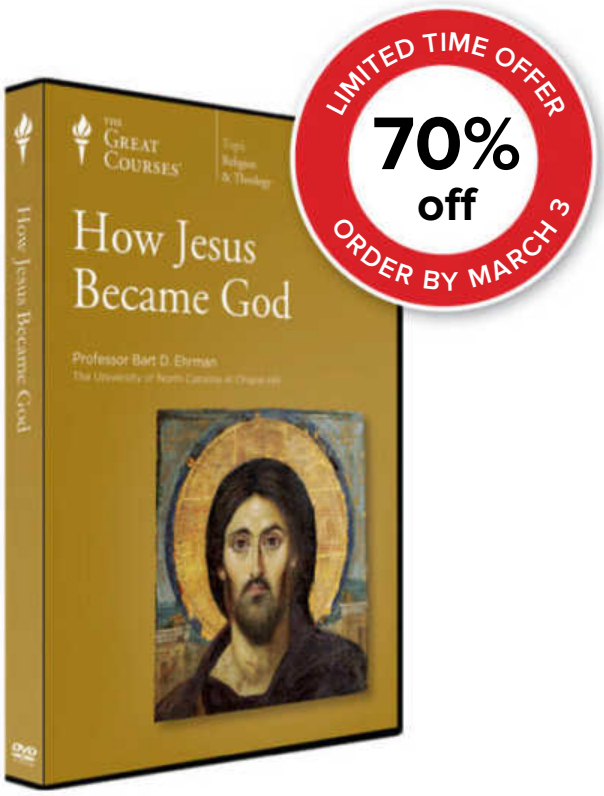
Mention promotional code 102516.

1-844-236-3827

Jacuzzi

82019

THE GREAT COURSES®



Uncover the Extraordinary Story of Jesus Christ

The early Christian claim that Jesus of Nazareth was God completely changed the course of Western civilization. For that reason, the question of how Jesus became God is one of the most significant historical questions and, in fact, a question that some believers have never thought to ask. What exactly happened, such that Jesus came to be considered God? To ask this question is to delve into a fascinating, multilayered historical puzzle—one that offers a richly illuminating look into the origins of the Western worldview and the theological underpinnings of our civilization.

In the 24 provocative lectures of **How Jesus Became God**, Professor Bart D. Ehrman of The University of North Carolina at Chapel Hill takes you deeply into the process by which the divinity of Jesus was first conceived by his followers, demonstrating how this conception was refined over time to become the core of the Christian theology that has so significantly shaped our civilization.

Offer expires 03/03/16

THEGREATCOURSES.COM/9DISC

1-800-832-2412

How Jesus Became God

Taught by Professor Bart D. Ehrman
THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

LECTURE TITLES

1. Jesus—The Man Who Became God
2. Greco-Roman Gods Who Became Human
3. Humans as Gods in the Greco-Roman World
4. Gods Who Were Human in Ancient Judaism
5. Ancient Jews Who Were Gods
6. The Life and Teachings of Jesus
7. Did Jesus Think He Was God?
8. The Death of Jesus—Historical Certainties
9. Jesus's Death—What Historians Can't Know
10. The Resurrection—What Historians Can't Know
11. What History Reveals about the Resurrection
12. The Disciples' Visions of Jesus
13. Jesus's Exaltation—Earliest Christian Views
14. The Backward Movement of Christology
15. Paul's View—Christ's Elevated Divinity
16. John's View—The Word Made Human
17. Was Christ Human? The Docetic View
18. The Divided Christ of the Separationists
19. Christ's Dual Nature—Proto-Orthodoxy
20. The Birth of the Trinity
21. The Arian Controversy
22. The Conversion of Constantine
23. The Council of Nicea
24. Once Jesus Became God

How Jesus Became God
Course no. 6522 | 24 lectures (30 minutes/lecture)

SAVE UP TO $190

DVD ~~$269.95~~ NOW $79.95
CD ~~$199.95~~ NOW $59.95
+$10 Shipping, Processing, and Lifetime Satisfaction Guarantee
Priority Code: 122178

For over 25 years, The Great Courses has brought the world's foremost educators to millions who want to go deeper into the subjects that matter most. No exams. No homework. Just a world of knowledge available anytime, anywhere. Download or stream to your laptop or PC, or use our free mobile apps for iPad, iPhone, or Android. Over 550 courses available at www.TheGreatCourses.com.